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ARMY RESEARCH LABORATORY

A USER GUIDE FOR THE DELTAED RADIATIVE TRANSPORT MODEL

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Under Contract DAAL03-91-C-0034
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This report is a user guide for a modified version of the delta-Eddington based visible contrast computer model DELTAED. The original DELTAED model was modified to use the EOSAEL card order-independent input format convention, which renders input card decks more readable and less prone to error. The output of the original DELTAED model was also modified to make code results more readable to the casual DELTAED user. A sky-to-ground ratio calculation mode was also added to the code. Several example runs of the modified code using data from the original DELTAED technical guide are included for comparison with the DELTAED results shown in that document. In addition, four new example cases that illustrate some of the capabilities of the modified code are also included.

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1. DELTAED MODEL STRUCTURE AND DESCRIPTION

1.1 Introduction

The basic structure of the DELTAED code[1] and how it cycles are illustrated by the flow diagram in figure 1. The diagram shows that the program execution flow is essentially linear, with only the optional call to SPECTALB interrupting the unconditional execution of major subroutines.

The DELTAED program accesses data for input or output from seven FORTRAN logical units: 2, 3, 4, 5, 9, 10, and 12. The usage of these logical units is summarized in table 1. Note that due to the internal cycling of the new version of the code, the file containing surface reflection function data is attached to logical unit 9 and is opened at the beginning of each input data cycle and closed at the end of each cycle. The logical unit 5, where user input resides, remains open during the entire DELTAED run. This contrasts with the single pass structure of the old version of the code where logical unit 5 first is used to read in the user input data and is then closed and reopened to read in the surface reflectance data.

Also new to the code is the use of temporary scratch files attached to logical units 2, 3, and 4. Logical unit 2 contains only the user input card images for the current input data cycle. This input is used by a new subroutine named REGEN that regenerates a complete cycle of input card images. Logical unit 4 is used to store incoming PHF1 and PHF2 phase function card images for later integration into the complete input cycle of card images, which are then written to logical unit 3 by REGEN. The INPUT subroutine then reads its input from the REGENerated input deck. This mode of input procedure ensures that input data is correctly initialized for second and following input data cycles. The use of the logical unit 4 phase function data buffer significantly reduces static array storage requirements.

A user also may make use of the new plot file DATAED.PLT that is attached to logical unit 12. This logical unit is opened and used exclusively in the OUTPUT subroutine.

---

[1]John M. Davis, 1990, An Evaluation of the delta-Eddington Visible Contrast Transmission Model, Final Report, Contract No. DAAL03-86-D-0001, Delivery Order 1685, Scientific Services Program.

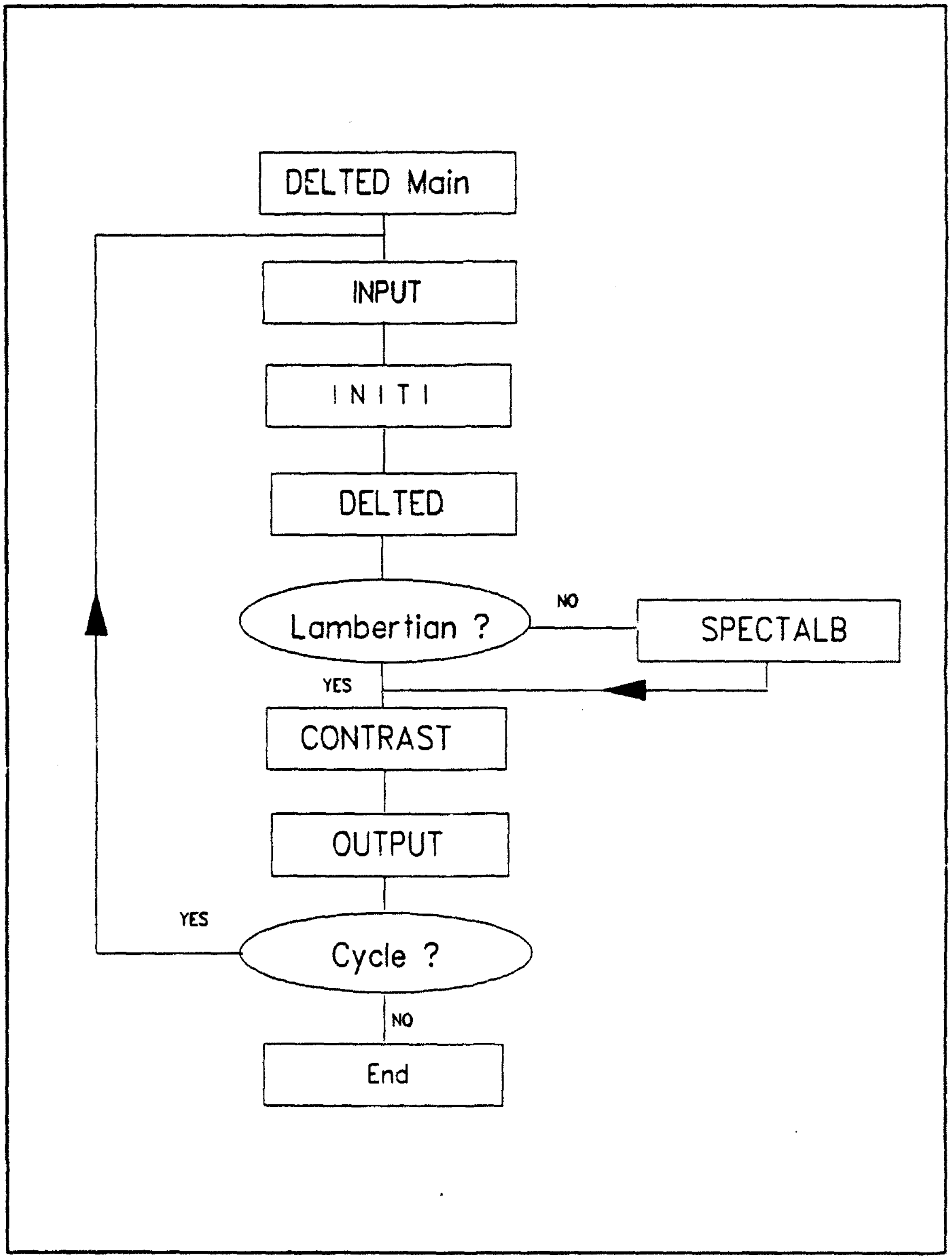

Figure 1. Basic structure and sequencing of DELTAED code.

TABLE 1. FILES USED BY DELTAED MODEL

File Name(s)	LU Number	LU Variable	Description
Scratch)	2	LUSCR	Partial input cycle scratch file
(Scratch)	3	LUSCR3	Complete input cycle scratch file
(Scratch)	4	LUPFN	Phase function input cycle scratch file
DATAED.INP	5	LUIN	User input file
SURFACE LAM.606 FOR.606 BOG.606 SAV.606 PAS.606	9	LUSURF	Biconical surface reflectance and albedo file (file attached to LUSURF depends upon value of NUSLAM parameter)
DATAED.OUT	10	LUOUT	Output results and errors text file
DATAED.PLT	12	LUPLOT	Output plot file

1.2 Subroutine Descriptions

1.2.1 Program DELTAED

The main program DELTAED sequences the INPUT, INITI, DELTED, SPECTALB, CONTRAST, and OUTPUT modules as shown in figure 1. It is here that the input data cycling is explicitly controlled.

1.2.2 Subroutine INPUT

When called by the DELTAED driver, INPUT handles all the intake of user-defined environment and control data. The data that it reads in are ultimately from the DATAED.INP and the surface reflectivity file that the user attaches to logical unit 9 (LUSURF). After performing various initializations, INPUT calls the REGEN subroutine that buffers the input data in DATAED.INP to various scratch files. The buffering of input data to scratch files ensures that the physical scenario described by the current and subsequent cycles of input data is properly initialized. Otherwise, some arrays whose initial values are written over during one cycle may invalidate the results of the next cycle. Upon return to INPUT, the buffered data are read from the scratch file attached to logical unit 3.

The input data records in DATAED.INP are read in under the EOSAEL card order-independent format. In this scheme, a four-letter tag at the beginning of the card record signifies what data follow on the rest of the record. Each card record is first read into an 80 character buffer. Then, this buffer is read as an internal file under the standard EOSAEL format specification of (2A4,2X,7E10.4), and the first (tag) field is then tested against an array of known identifiers. If one of the known tags is matched, the parameters read in under the 7E10.4 portion of the field are assigned to DELTAED input variables appropriate to the recognized tag. If none of the array of known identifiers matches the input tag, an error message is printed and program execution terminates.

A full description of the library of input card identifiers is given in section 2.

1.2.3 Subroutine REGEN

REGEN buffers data read in from the DATAED.INP file to various scratch files for later use by the INPUT subroutine. On the first cycle of input data, REGEN sets flags and counters to indicate which options are in effect and how many cards of different kinds have been read. On subsequent passes, REGEN regenerates a new complete deck of input records from the records used by the previous cycle and any new cards that appear in the current input data cycle.

The following diagram (figure 2) shows schematically how REGEN accesses the scratch files:

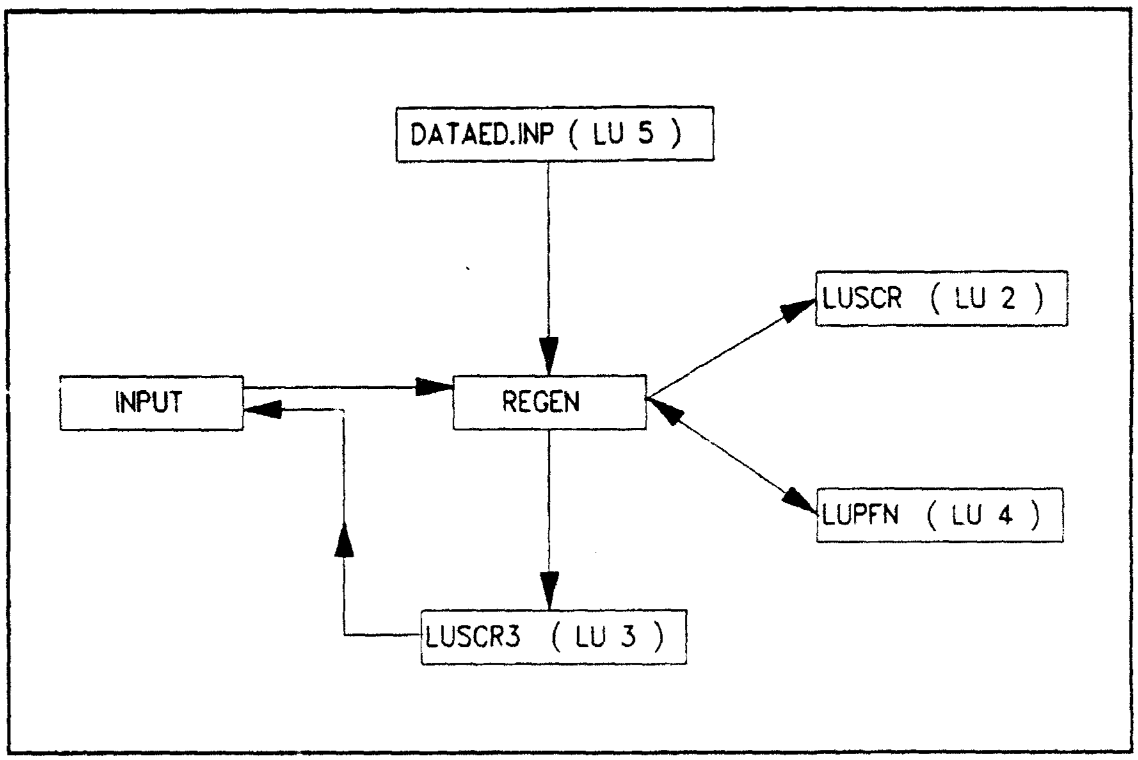

Figure 2. Scratch file usage by REGEN.

1.2.4 Subroutine SUNPOS

The solar zenith angle and apparent azimuth angle are computed by the SUNPOS routine, which is called by INPUT when the SUNB input card is encountered. SUNPOS calls the DEC and EOT functions during its calculations. This routine is normally called when the user wishes path radiance and contrast calculations as a function of time or observer location on the earth.

The SUNPOS routine takes observer longitude and local time among its other inputs. Special caution must be taken because the standard meridian for the observer is computed rather than input by the user. This meridian defines a longitude that is a certain number (TZONE) of hours east or west of the standard meridian at Greenwich, England, with westerly meridians being negative. The TZONE parameter on the SUNB card determines which standard meridian is used to define the observer's local time. See the description of the SUNB card in section 2 for more specific details about the use of the TZONE parameter.

1.2.5 Real Function DEC

The DEC function computes the earth's polar axis declination angle relative to the sun. From the observer's point of view, and using the customary (right ascension, declination) coordinates on the celestial sphere, the quantity computed is the declination of the sun. For example, at the winter solstice the computed declination is -23.44 degrees; at the vernal or autumnal equinoxes, the declination value is zero. The formulation used in this routine is a sinusoidal approximation to tabulated data.

1.2.6 Real Function EOT

The value of the equation of time (in minutes) is computed by the EOT function. The equation of time is the difference between the time at which the mean sun transits the observer's local meridian and the time at which the apparent sun transits. The nonzero value of this quantity arises from the elliptical nature of the earth's orbit around the sun. The mean sun position is calculated on the basis of a circular orbit. The rather small deviation of the actual orbit from circular causes the apparent (observed) sun to lead or lag the mean sun predicted transit times during the year. As in the DEC case, the formulation used here is an approximation to tabulated data.

1.2.7 Subroutine INITI

The INITI subroutine initializes arrays and makes preliminary calculations that set up the delta-Eddington model that is implemented in the DELTED subroutine. Included in these initializations is that of the DIAG logical diagnostic flag, which is set to a value of FALSE. The user may change this flag to TRUE and recompile the program to enable printout of critical model performance parameters. INITI calls the SIGRAY function to calculate the Rayleigh molecular scattering coefficient.

1.2.8 Real Function SIGRAY

The SIGRAY function calculates the Rayleigh molecular scattering coefficient for a given wavelength in micrometers and atmospheric mass density in grams per cubic meter. At a wavelength of 0.55 μm and at the standard atmospheric density of 1293 g m^{-3} (for dry air at 273 K and 1013 mbar), SIGRAY predicts a value of 0.01237 km^{-1} for this scattering coefficient. SIGRAY is called by the INITI routine.

1.2 9 Subroutine DELTED

The DELTED subroutine performs the balance of the delta-Eddington solution by calculating the fluxes and path radiance functions for the user-defined physical scenario. DELTED calls the following routines and functions: ELIMIN, PATHRAD, BSL1F, and SIMPNE.

1.2.10 Subroutine PATHRAD

Subroutine PATHRAD calculates the path radiance function for the DELTED routine. Analytically, the path radiance function is the path radiance per unit length at any point along a given line of sight (LOS). Numerically, the path radiance function is the finite increment of path radiance contributed by a finite segment of a given LOS.

1.2.11 Subroutine SPECTALB

When a non-Lambertian ground surface is specified by the user, the SPECTALB routine is called to perform the modifications by the incident diffuse radiation field to the surface albedo and the surface's bidirectional reflectance.

1.2.12 Subroutine ELIMIN

The definition of the delta-Eddington problem for a plane-parallel geometry with boundary and continuity conditions leads to a set of 2*NLEV simultaneous linear differential equations. The ELIMIN routine solves this system using the Gauss-Seidel algorithm. The solution provides values for coefficients that yield radiance and flux values in each atmospheric model layer.

1.2.13 Subroutine WEIGHT

Subroutine WEIGHT is called by INTERP to provide weighting factors used for interpolations of quantities defined on the unit sphere between points defined on the unit sphere. The weighting factor is computed as the inverse distance on the unit sphere separating the interpolation point from nearby given values. Only those given points within 60 degrees of the interpolation point are considered. A smoother interpolated field may be obtained by increasing the size of the DELTA parameter in this routine, at the expense of slower execution.

1.2.14 Subroutine INTERP

Functions RDIF and RDIR call INTERP to provide interpolations for arbitrary points on the unit sphere of quantities defined by arrays of discrete points on the unit sphere.

1.2.15 Real Functions BSL1F,BSL1D, and Subroutine BSL1NT

Given an arbitrary scattering cosine, subroutines DELTED and CONTRAST use the BSL series of routines and functions to interpolate a phase function value for a phase function specified over a discrete grid of scattering cosines.

1.2.16 Real Functions SIMPSN and SIMPNE

Numerical integration of path-dependent quantities in the CONTRAST and DELTED routines is handled by this pair of functions. These routines will occasionally fail when the user specifies too few atmospheric layers with the ATM1, ATM2, and AERO cards. The usual symptom of such a failure is the appearance of negative path radiance values that are flagged by the model and end execution. The reason these negative values occur is that when too few layers are specified, the optical depth of some portions of the LOS may be large. When this happens, the quantity integrated by SIMPNE and SIMPSN, the product of transmission and the path function, may vary quite sharply at points along the path and yield negative interpolated ordinates. The solution to this problem is to subdivide the problem region more finely.

1.2.17 Subroutine CONTRAST

The CONTRAST subroutine calculates path radiance for all LOS defined by observer-target positions on the OBS1, OBS2, TGT1, and TGT2 cards. It does so by integrating the product of the path function and transmittance over each LOS, using the SIMPNE function. If non-Lambertian ground surfaces are selected on the SURF card by the user, CONTRAST also calls the RDIF and RDIR functions. CONTRAST also calls an augmented exponential function, EXPF, that traps underflow conditions.

1.2.18 Real Function EXPF

The EXPF function is called by CONTRAST when exponentials of optical depths are calculated. To guard against underflows, EXPF traps arguments with absolute values greater than 25 and sets the return value of the function equal to zero.

1.2.19 Real Function RDIR

When a non-Lambertian ground surface is selected by the user, the RDIR function supplies the anisotropic reflectance for the direct beam. It does so by interpolating over angle for the given LOS direction and given the solar zenith angle for the problem. The interpolation is performed only over that portion of the reflectance array (read in from logical unit 9) that is appropriate for the given solar zenith angle.

1.2.20 Real Function RDIF

When the user selects a non-Lambertian ground surface, the RDIF function supplies the surface diffuse reflectance as weighted by the incident diffuse irradiance. Here, "incident diffuse irradiance" is defined as the integral of incident radiance over the downwelling hemisphere, weighted by the cosine of the incident zenith angle. The reflected diffuse irradiance is similarly defined for the upwelling hemisphere. The ratio of the reflected diffuse irradiance to the incident diffuse irradiance defines a surface albedo that varies with the angular

distribution of the incident illumination. This modified albedo is used in the radiative transfer calculations for the diffuse radiance.

1.2.21 Subroutine OUTPUT

Final output of path and surface radiance quantities is performed by the OUTPUT subroutine. If the ISGRA parameter signals that the sky-to-ground (S/G) ratio calculation mode is active, then sky path and ground path radiances and other quantities are output as well. Also in this routine, some of the DELTAED results are output to an ASCII format file (DATAED.PLT) attached to logical unit 12. Further details of the format and content of OUTPUT results are given in section 3.

1.2.22 Subroutine LOSTAU

The OUTPUT subroutine calls LOSTAU to provide a slant-path transmission T from the observer to the ground target when the S/G ratio calculation is performed. This in turn is combined with the S/G ratio σ to calculate the contrast transmission T_C for the ground path LOS using the relation

$$T_C = \frac{1}{1 + \sigma \left(\frac{1}{T} - 1 \right)} .$$

Note that for LOS other than the ground target LOS, the user must recalculate T and use the expression above to calculate an appropriate contrast transmission.

2. DELTAED INPUT DESCRIPTION

2.1 Introduction

One apparent difference between the version of DELTAED documented here and the previous version is the revised format of user input. The new input format is designed to enhance the readability of input files. Thus, users who create many such files during substantial projects will find the file maintenance task easier to manage.

The cyclic nature of input, delimited by the GO and DONE sentinel cards, is also a new input feature. Most users have screen editors that can replicate blocks of text within an input file. Using such block copies followed by appropriate editing of the copied blocks, the user can create files that vary a study parameter over a specified range. Practical examples of this will be seen in section 3.

The next section describes the input format and contents in some detail. That section is followed by a section describing general cautions on input data format and content for single and multiple cycle DELTAED runs. The prospective user of the DELTAED code is well advised to carefully examine these sections.

2.2 Descriptions of Individual Input Records

The input cards for DELTAED are listed on the following pages. Each card consists of an identifier (tag) field followed by up to seven parameters in floating point format. The format under which these cards are read is (2A4, 2X, 7E10.4). Only the first four letters of the identifier field are significant. In the description below, each card identifier is followed by a list of input variables and an explanation of the meaning and permissible values of each variable.

The role that each card plays in allowing the user to specify the DELTAED physical scenario is readily seen by a functional grouping of input card identifiers. Table 2 shows such groupings by function, with the applicable card identifiers. The maximum number of cards in each group that may be present in any single input data cycle is also indicated by the MAX parameter.

TABLE 2. INPUT IDENTIFIER GROUPS

Group Function	Group Identifiers	Maximum Number
Solar geometry	SUNA, SUNB	MAX = 1
Atmospheric level definition	ATM1, ATM2	MAX = 22 (NLEV <= 21)
Aerosol layer properties	AERO	MAX = 21 (N <= NLEV-1)
Aerosol phase function properties	PHF1, PHF2	MAX = 3620 (NLA <= NLEV-1) (NANG() <= 180)
Observer geometry	OBS1, OBS2	MAX = 31 (NOBS <= 30)
Target geometry and reflectivity	TGT1, TGT2	MAX = 30 (NTARG <= 29)
Ground surface type	SURF	MAX = 1
Sky-to-ground ratio switch	SGRA	MAX = 1
Terminators	GO , DONE	MAX = 1

Card identifier: SUNA

Variables: THETO, PHIO

The SUNA and SUNB cards are used to specify the zenith angle and azimuth of the sun in the sky. SUNA is used for direct user specification of these quantities.

SUNB allows for specification of the user's position on the earth and the local time to determine the solar zenith and azimuth angles. Note that if SUNA and SUNB cards are both present in the same input cycle, the SUNA inputs will override the SUNB inputs.

THETO - Zenith angle of the sun, in degrees.

PHIO - Azimuth angle of the sun, in degrees. The azimuth convention used here is the heading of the sun from the observer's point of view. Looking down upon the observer, the azimuth is measured clockwise from north. Thus, an easterly heading is 90 degrees, a southerly heading is 180 degrees.

Card identifier: **SUNB**

Variables: **OLAT, OLONG, STTIME, IDAY, MONTH, TZONE**

OLAT - Observer's latitude, in degrees (positive north, negative south)

OLONG - Observer's longitude, in degrees east of Greenwich (use negative values for west of Greenwich)

STTIME - Observer's local time, given in the 24-h (military format) HH.MM; for example, 17.30 = 17 h 30 min local standard time

IDAY - Day of the month (valid range 1-31 for MONTH=1, 1-28 for MONTH=1, etc.)

MONTH - Month of the year (valid range 1-12)

TZONE - Number of hours that the observer's local time zone is ahead of (positive) or behind (negative) Greenwich time [Universal Time (UT)].

For example, Eastern Standard Time (EST) is 5 h behind UT. If the observer is in this EST time zone the value TZONE = -5.0 should be used. Similarly, for observers using Central Standard Time as the local standard time, TZONE = -6.0. For observers in the UT zone, use TZONE = 0.001. Here are appropriate TZONE values for the continental United States (ST = standard time, DT = daylight time):

EST: TZONE = -5.0

EDT: TZONE = -4.0

CST: TZONE = -6.0

CDT: TZONE = -5.0

MST: TZONE = -7.0

MDT: TZONE = -6.0

PST: TZONE = -8.0

PDT: TZONE = -7.0

If TZONE is set to zero, the observer's standard meridian is set to a value of 15.0*AINT(OLONG/15.0) degrees, where the AINT function truncates the fractional part of the quotient OLONG/15.0. Thus, for example, if TZONE = 0.0 and OLONG = -106.0, then the standard meridian is -105.0 degrees [which would be appropriate to Mountain Standard Time(MST)]. If OLONG were then changed to -104.0 degrees, and if TZONE = 0, the computed standard meridian.

Card identifier: **ATM1**

Variables: **NLEV, XLAM, VIS**

The ATM1 and ATM2 cards are used to define the atmospheric density profiles that in turn define the vertical profile of the Rayleigh molecular scattering coefficient. Also defined (on ATM1) are the wavelength for the problem and the surface visibility at a wavelength of 0.55 μm. NLEV must be greater than or equal to 2.

NLEV = Number of levels at which the atmospheric profile is defined

XLAM = Wavelength, in micrometers

VIS = Surface visibility at a wavelength of 0.55 μm, in kilometers

Card identifier: **ATM2**

Variables: **NL, Z(NL), PRES(NL), RHO(NL)**

Note that the ATM2 cards should be set up so the levels Z(NL) decrease monotonically as the index NL increases. Failure to observe this convention will lead to either erroneous results or a program crash.

NL = Index of atmospheric level at which the following quantities are defined

Z(NL) = Height of level NL, in kilometers

PRES(NL) = Atmospheric pressure at level NL, in millibars

RHO(NL) = Atmospheric density at level NL, in grams per cubic meter

Card identifier: **AERO**

Variables: **N, A(N), G(N), BETAA(N)**

The AERO card defines the scattering properties of aerosols in each atmospheric layer. Note that the maximum value that N may assume is equal to NLEV-1, the number of AERO cards that must be present. Also note that N is associated with the layer whose lower level is given by the index NL-1, where NL is an index value on the ATM2 card above.

N - Atmospheric layer in which the following quantities are specified

A(N) - aerosol single-scattering albedo (dimensionless)

G(N) - aerosol asymmetry parameter (dimensionless)

BETAA(N) - aerosol extinction coefficient, in kilometers^{-1}

Card identifier: **PHF1**

Variables: **NLA, NANG(NLA)**

The PHF1 and PHF2 cards define the aerosol scattering phase function over a set of angles in each layer. For the AERO card, exactly NLEV-1 PHF1 cards must be present in the input deck. If NANG(NLA) is input as 0 for any layer NLA, no PHF2 cards should be included in that layer. A Henyey-Greenstein phase function is assumed for the NANG(NLA)=0 case.

NLA - Number of layer in which the following number of phase function angles is specified

NANG(NLA) - Total number of angles at which the phase function is specified in layer NLA

= 0 for Henyey-Greenstein phase function

> 0 for user-input phase function (exactly NANG(NLA) PHF2 cards must then be present for layer NLA)

Card identifier: **PHF2**

Variables: **NLA, NA, ANG(NA,NLA), PF(NA,NLA)**

NLA - Number of layer in which the following quantities are specified

NA - Angle number

ANG(NA,NLA) - Angle at which following phase function value is specified, in degrees

PF(NA,NLA) - Phase function value at angle ANG(NA,NLA)

Card identifier: OBS1

Variable: NOBS

The OBS1 and OBS2 cards are used to specify the observer end of each LOS. Up to 30 observer points may be specified (that is, NOBS must be less than or equal to 30). Note that in the S/G calculation mode (ISGR = 1), NOBS must be set equal to 1 (only one observer is allowed in this case).

NOBS - Total number of observing points

Card identifier: OBS2

1Variables: NO, XOB(NO), YOB(NO), ZOB(NO)

NO - Observer number

XOB(NO) - X-coordinate of observer, in kilometers (positive east, negative west)

YOB(NO) - Y-coordinate of observer, in kilometers (positive north, negative south)

ZOB(NO) - Z-coordinate of observer, in kilometers (positive up)

Card identifier: TGT1

Variable: NTARG

The TGT1 and TGT2 cards are used to specify the target end of each LOS. Up to 29 target points may be defined in each input cycle, but note that only 2 may (and must) be specified if the S/G calculation mode is active (ISGR = 1). Furthermore, if the S/G mode is active, the first TGT2 target card is used to define the sky (horizon) path and the second is used to define the ground path.

NTARG - Total number of target points

Card identifier: TGT2

Variables: NT, XTARG(NT), YTARG(NT), ZTARG(NT), THTARG(NT), AZTARG(NT), RTARG(NT)

NT - Target number

XTARG(NT) - X-coordinate of target, in kilometers (positive east, negative west)

YTARG(NT) - Y-coordinate of target, in kilometers (positive north, negative south)

ZTARG(NT) - Z-coordinate of target, in kms (positive up)

THTARG(NT) - Zenith angle of normal to target's surface, in degrees (for example, target plane parallel to ground has THTARG()=0, target plane perpendicular to ground has THTARG()=90)

AZTARG(NT) - Azimuth of normal to target's surface, in degrees (measured west of south, for example, a target facing south for nonzero THTARG() has AZTARG()=0, one facing west has AZTARG()=90)

RTARG(NT) - Reflectivity of target (dimensionless). When this quantity is greater than or equal to zero, the target is assumed to be Lambertian, with albedo RTARG(NT). When RTARG(NT) is input as any negative number, the absolute value of the number is ignored and the reflectivity of the target is the same as the ground surface.

Card identifier: SURF

Variables: NUSLAM, ALBED

The SURF card determines whether the ground surface reflectivity is Lambertian or non-Lambertian. The user may choose (via NUSLAM) from a small library of biconical reflectances from vegetated surfaces[2] or specify his or her own non-Lambertian surface (in file SURFACE).

NUSLAM = Surface reflectivity flag:

= 0 for Lambertian surface

= 1 for boggy surface

= 2 for forested surface

= 3 for savanna surface

= 4 for pasture surface

> 4 for user-defined biconical reflectivity file

ALBED = surface albedo (dimensionless)

Note: The format of the biconical reflectance file is the following (the current layout shown here has NSAZ=7, NSNA=10, and NZEN=10):

Record 1: NSAZ, NSNA, NZEN (format: 3I5)

Record 2: DIRREF(1,1,1), DIRREF(1,1,2), ... , DIRREF(1,1,10) (format 10F7.4)

Record 3: DIRREF(1,2,1), DIRREF(1,2,2), ... , DIRREF(1,2,10)

.
.
.

Record 71: DIRREF(10,7,1), DIRREF(10,7,2), ... , DIRREF(10,7,10)

Record 72: ALBEDO

Another way to show the organization of this file is to show the program fragment that actually reads the reflectance data from the file:

```
      DO 140 I= 1,NZEN
         DO 150 J=1,NSAZ
            READ(LUSURF,1220) (DIRREF(I,J,M), M=1,NSNA)
  150    CONTINUE
  140 CONTINUE
```

[2]K. T. Kreibel, 1977, <u>Reflection properties of vegetated surfaces: tables of measured spectral biconical reflectance factors</u>," Wissenschaftlliche Mitteilung Nr. 29, Universitat Munchen Meteorologisches Institut, Theresienstrasse 37, 8000 Munchen 2., West Germany.

Here, NSAZ is the number of surface azimuth angles, NSNA is the number of surface nadir angles, NZEN is the number of zenith angles at which the biconical reflectance is defined, DIRREF is the reflectance value, and ALBEDO is the optional surface albedo. Currently, ALBEDO is set to zero in the reflectance files, but a user can edit the file to insert a nonzero value. This value may be accessed (that is, used in place of ALBED) by specifying an ALBED value on the SURF card that is zero or greater than 1.

Card identifier: **SGRA**

Variable: ISGR

The ISGR flag activates or deactivates the S/G calculation mode. Note that certain conditions on input parameters must be met when the S/G mode is active:

(1) NOBS must be equal to 1

(2) NTARG must be equal to 2

(3) The first target is the sky; it should be a long distance away (100 km is a good value to use) and nearly level with the observer

(4) The second target is the ground

(5) The ground target normal should be vertical (THTARG(2) = 0.0)

(6) The ground target should have the same albedo as the ground (that is, RTARG(2) should be equal to ALBED on the SURF card)

ISGR = S/G calculation flag

= 1 enables S/G calculation

<> 1 disables S/G calculation

Card identifier: **GO**

Variables: None

The GO card closes the current cycle of DELTAED input cards, but does not terminate input to DELTAED. This latter task is handled by the DONE card.

Card identifier: **DONE**

Variables: None

This card will terminate the DELTAED input stream and hand off to the DELTAED driver to begin execution. The presence of this card indicates that the input cycle in which it is located is the final input data cycle.

2.3 Cautions About Input Data

Note that for successful recognition by the INPUT subroutine, each card identifier may only have letters that are all uppercase or all lowercase. For

example, the acceptable "SUNA" and "suna" cards will point to the same (appropriate) list of variables, but "Suna" or "suNa" will be interpreted as unknown input and will terminate the program with an error. Should the message "A NON EOSAEL FORMAT INPUT CARD ENCOUNTERED IN: INPUT" appear, the user should first inspect the DATAED.INP file to be sure that the all uppercase or all lowercase convention is observed.

Also, note that if new cards that redefine the atmospheric layer models (that is, cards that have tags using the (ATM1, ATM2), (AERO), or (PHF1, PHF2) input identifier groups) appear in any input data cycle, the entire layer specification must be repeated for the group(s) in which the new cards appear. The reason for this inconvenience is that the current version of the REGEN input buffer routine reinitializes counters that check to verify that the number of layers or levels actually read in is appropriate to the number of levels specified on the ATM1 card.

As an example of the above redefinition requirement, consider a case where the NLEV parameter on the ATM1 card is 16 on the first DELTAED execution cycle. Then 15 AERO and 15 PHF1 cards must also be present in this cycle. If any of the NANG() parameters are nonzero on the PHF1 cards, then NANG() PHF2 cards must also be present for each of the affected layers. On the second DELTAED execution cycle, suppose that the user wants to change only the value of the aerosol extinction coefficient in one of the atmospheric layers. In that event, 15 new AERO cards (14 of which are duplicates from the previous cycle and the single modified card) must be present in the second cycle input. None of the ATM1,ATM2 or PHF1,PHF2 card sequences need to be duplicated for the second cycle, because the layer boundaries specified on the ATM1,ATM2 cards and the phase functions specified on the PHF1,PHF2 cards do not change.

If the user changes the value of the NLEV parameter on the ATM1 card between cycles, the AERO and PHF1,PHF2 card sequences must also reflect that change. To this end, the entire atmospheric model (defined by ATM1,ATM2, AERO, and PHF1,PHF2 card sequences) must be respecified in the input deck. The user should confine such global changes to separate DELTAED runs and vary only geometrical or time dependent parameters between cycles within a run.

3. DELTAED OUTPUT DESCRIPTION

3.1 Introduction

Along with the user input portion of the DELTAED code, the output routine OUTPUT has been substantially revised to enhance readability and allow for convenient display of critical parameters. Results from the new S/G ratio calculation mode are also optionally output. Another new feature is the use of a plot data file to collect output data in a file named DATAED.PLT for later use by plotting or spreadsheet software. The simple organization of the output data is shown in figure 3. Also shown in this figure are possible postprocessing destinations for the OUTPUT data.

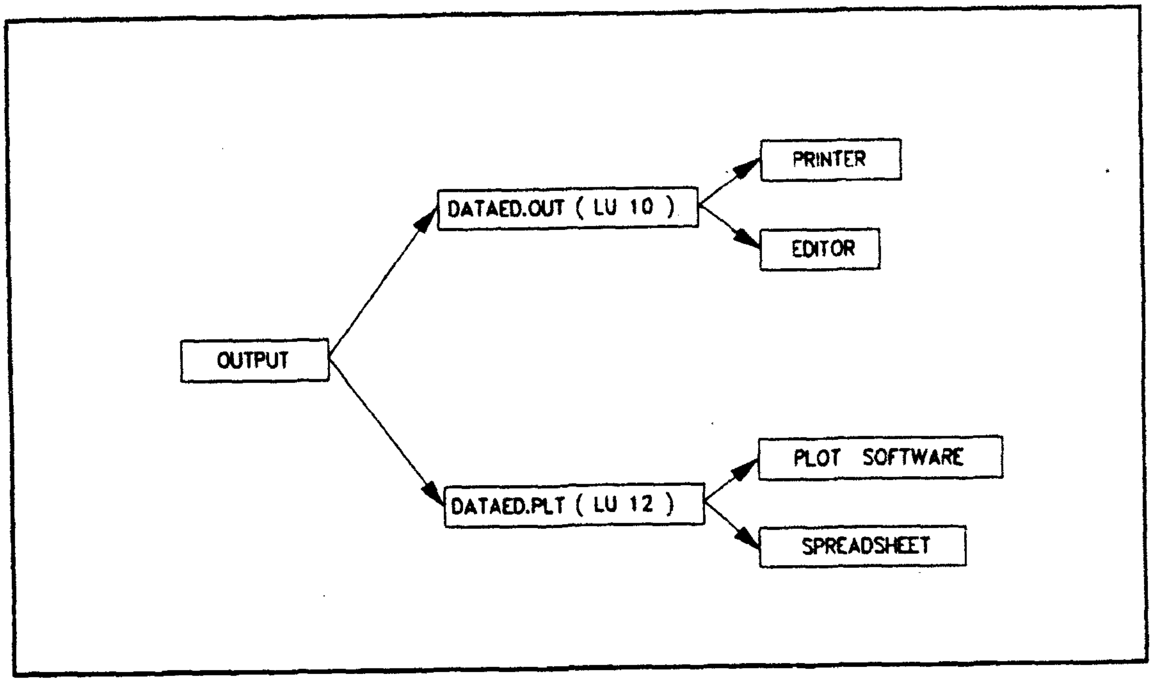

Figure 3. Subroutine OUTPUT data flow.

3.2 Output Cycle Description

The new output format for each cycle of data sent to the DATAED.OUT file arranges the output into blocks of related parameters. If the S/G ratio calculation is invoked by setting ISGRA to 1 on the SGRA card, a block detailing the results of that calculation is also sent to the DATAED.OUT file. The content of each output block in a given execution cycle may be summarized as follows:

(1) Input card echo: the card images for this cycle are present in the DATAED.INP file (logical unit 5)

(2) Atmospheric model profile specifications: the parameters used to specify the model atmosphere used for the current execution cycle are shown. Included are the following:

(a) base height of each layer

(b) Rayleigh extinction coefficient at the base of each layer

(c) aerosol extinction coefficient at the base of each layer

(d) total extinction coefficient at the base of each layer

(e) optical depth for a vertical path from the top of the atmosphere to the bottom of each layer

(3) Surface parameter specifications:

(a) solar zenith and azimuth angles

(b) surface visibility

(c) total atmospheric optical depth for a vertical path from the surface to the top of the atmosphere

(d) ground surface type (Lambertian or non-Lambertian)

(4) LOS parameters:

(a) LOS zenith and azimuth angles

(b) LOS path radiance

(c) intrinsic (zero observer range) radiance of target

(d) total LOS radiance seen by observer

(e) target normal orientation angles

(5) Contrast parameters (generated only if ISGRA = 1):

(a) sky path zenith and azimuth angles

(b) sky path range (usually 100 km)

(c) sky path radiance

(d) ground path zenith and azimuth angles

(e) ground path range

(f) ground path radiance

(g) ground path intrinsic surface radiance

(h) ground path transmission T

(i) input ground surface albedo

(j) computed S/G ratio

(k) contrast transmission for selected ground path

It is important to observe that the solar irradiance incident at the top of the atmosphere (signified by the FNOT variable in the DELTAED program) is set to a value of 1.0. The solar flux scales the radiance results in the entire DELTAED algorithm. This means that the path radiances and surface radiances listed above are normalized and must be multiplied by the solar irradiance to yield normal physical radiance units (for example, watts per square meter per steradian).

Printed examples of output data collected in the DATAED.OUT file may be seen in the next chapter.

In addition to the DATAED.OUT output just mentioned, result data are also sent to the DATAED.PLT ASCII file for subsequent plotting or analysis. The format of these data depends upon whether or not the user has used the S/G ratio calculation mode. The format of each possible mode is seen in the following:

(1) Standard mode (no S/G calculation):

(a) output data (in order of appearance): THETO, PHIO, THETOB(L), PHIOB(L), PTHRD(L), SURFO(L), PTHRD(L)+SURF(L), VIS, ALBED, OLAT, OLONG, STT, IDAY, MONTH

where

THETO - solar zenith angle (degrees)
PHIO - solar azimuth angle (0 to 360 degrees)
THETOB(L) - zenith angle of LOS number L
PHIOB(L) - azimuth angle of LOS number L
PTHRD(L) - path radiance of LOS number L
SURFO(L) - intrinsic target radiance for LOS number L
PTHRD(L)+SURF(L) - total LOS radiance for LOS number L
VIS - surface visibility (kilometers)
ALBED - input ground surface albedo
OLAT - observer latitude
OLONG - observer longitude
STT - observer's local time
IDAY - day of the specified month (1-31)
MONTH - month of the year (1-12)

(b) format of output: (12(1PE11.4,1x),2(I3,1x))

(2) S/G mode:

(a) output data (in order of appearance): THETO, PHIO, THETOB(2), PHIOB(2), SGR, CTRANS, OLAT, OLONG, STT, IDAY, MONTH

where variables are as above, except for

THETOB(2) - zenith angle of ground path (degrees)
PHIOB(2) - azimuth angle of ground path (degrees)
SGR - S/G ratio
CTRANS - contrast transmission for ground path

(b) format of output: (9(1PE11.4,1x),2(I3,1x))

4. SAMPLE DELTAED CASES

4.1 Introduction

The following examples show how the new version of the DELTAED code may be run to study practical problems. First, the new version of the code was run to compare with the previous version for five cases given in the original DELTAED

documentation[1]. The results of the comparison are summarized in the next section.

Four new examples then serve to illustrate some of the new capabilities of the revised DELTAED code.

4.2 Comparisons with Old Version of DELTAED

The five cases reported in the original DELTAED documentation may be enumerated by the following list of their characteristics:

Case 1. This example shows the effect of target position and orientation relative to the sun. The sun is at a fixed position in the sky: zenith angle of 60 degrees and azimuth of 45 degrees east of north. The observer is located 101 m above the origin and looks at five targets. The targets are at the same level as the observer and are all at a range of 3.0 km. The targets are distributed in azimuth in 45 degree increments from north to south. The target normals are all horizontal (THTARG() = 90 degrees) and point directly at the observer (since the target normal's azimuth is measured to the west of the south direction, opposite of the convention for all other azimuths in the scenario geometry). The targets are Lambertian with an albedo of 0.15, and the ground surface is modeled by the non-Lambertian bog reflectance model with an albedo of 0.05081. The output of this case is shown in Listing 1.

Case 2. This example is identical to Case 1 except the input solar azimuth is changed to -45 degrees (or, using the north bearing convention 315 degrees). Listing 2 shows the results for this case.

Case 3. The third example illustrates the effect of introducing a cloud layer into the atmosphere. This case is the same as Case 2 except a 200-m thick layer with an extinction coefficient of 16.63 km^{-1} has been introduced, and the surface albedo has been changed to 0.05306. The output for this case is shown in Listing 3.

Case 4. This example replicates Case 3 except the observer-target geometry has been modified to allow a S/G ratio calculation. Note that the first LOS (the sky path) is horizontal and has a length of 100 km. The second LOS is only a bit over 14 m long from a height of 1.010 to 1.000 km. Note that for this comparison with the old version of the code, the new S/G calculation mode was not selected. Also observe that the elevated cloud layer does not affect the S/G ratio in the same way it would in reality, since the horizontal sky path does not intersect it in the plane-parallel geometry of the DELTAED model. The results of this case are shown in Listing 4.

[1]John M. Davis, 1990, An Evaluation of the Delta-Eddington Visible Contrast Transmission Model, Final Report, Contract No. DAAL03-86-D-0001, Delivery Order 1685, Scientific Services Program.

Case 5. The fifth example is identical to Case 4 except the Lambertian target is replaced by one with the same non-Lambertian (bog-type) reflectivity as the ground surface. This is accomplished by making the target albedo on the second TGT2 card negative. In this case, the absolute value of the target albedo is not used in the radiance calculations. Listing 5 shows the DELTAED output for this case.

The comparison of the new and old versions of DELTAED may be summarized by showing the path and surface radiances predicted by the two versions. The surface radiances shown here are intrinsic radiances (that is, zero target range).

Table 3 lists the comparison for Case 1. Note that in both cases, the first four targets (which are only illuminated by diffuse radiation) show a surface radiance that is much lower than that of the fifth (directly illuminated) target. Note that the path radiances in this case (as well as all the other cases) of the new and old versions are equal. However, the surface radiances shown by the two versions are not equal. The values predicted by the new version of the code were checked with hand calculations and found to be accurate. The reason for the difference between the new and old surface radiances was not apparent. Possibly the albedo of the target was modified in the old version of DELTAED in a manner inconsistent with the new version.

TABLE 3. COMPARISON OF OLD AND NEW VERSIONS OF DELTAED FOR CASE 1

	Old Version		New Version	
Target	Path Rad.	Surf. Rad.	Path Rad.	Surf. Rad.
1	1.75e-1	1.11e-2	1.75e-1	1.96e-2
2	4.47e-1	1.11e-2	4.47e-1	1.96e-2
3	1.75e-1	1.11e-2	1.75e-1	1.96e-2
4	8.24e-2	1.11e-2	8.24e-2	1.96e-2
5	6.52e-2	6.61e-2	6.52e-2	5.39e-2

The results for Case 2 are compared in table 4. Here the change of the solar azimuth is apparent in that only targets 1 and 2 are indirectly illuminated and the directly illuminated target surface radiances are symmetric about the antisolar direction of 135 degrees.

TABLE 4. COMPARISON OF OLD AND NEW VERSIONS OF DELTAED FOR CASE 2

	Old Version		New Version	
Target	Path Rad.	Surf. Rad.	Path Rad.	Surf. Rad.
1	1.75e-1	1.11e-2	1.75e-1	1.96e-2
2	8.24e-2	1.11e-2	8.24e-2	1.96e-2
3	6.52e-2	6.61e-2	6.52e-2	5.39e-2
4	6.11e-2	8.89e-2	6.11e-2	6.81e-2
5	6.52e-2	6.61e-2	6.52e-2	5.39e-2

Case 3 results are compared in table 5. Note the much reduced azimuthal dependence of both path and surface radiance caused by the cloud layer in this case. The surface radiance for the new version of DELTAED shows a greater reduction in the azimuthal dependence than does the old version.

TABLE 5. COMPARISON OF OLD AND NEW VERSIONS OF DELTAED FOR CASE 3

	Old Version		New Version	
Target	Path Rad.	Surf. Rad.	Path Rad.	Surf. Rad.
1	9.80e-2	2.03e-2	9.80e-2	2.42e-2
2	8.05e-2	2.03e-2	8.05e-2	2.42e-2
3	7.73e-2	3.00e-2	7.73e-2	2.43e-2
4	7.63e-2	3.40e-2	7.63e-2	2.43e-2
5	7.73e-2	3.00e-2	7.73e-2	2.43e-2

Results for the S/G ratio Cases 4 and 5 are shown in tables 6 and 7, respectively. The effect of changing the target reflectance characteristics from Lambertian to non-Lambertian is clearly seen in the much lower surface radiance from the non-Lambertian target of Case 5.

TABLE 6. COMPARISON OF OLD AND NEW VERSIONS OF DELTAED FOR CASE 4

	Old Version		New Version	
Target	Path Rad.	Surf. Rad.	Path Rad.	Surf. Rad.
1	1.82e-1	1.36e-2	1.82e-1	1.62e-2
2	2.15e-5	4.59e-2	2.15e-5	1.78e-1

TABLE 7. COMPARISON OF OLD AND NEW VERSIONS OF DELTAED FOR CASE 5

	Old Version		New Version	
Target	Path Rad.	Surf. Rad.	Path Rad.	Surf. Rad.
1	1.82e-1	1.36e-2	1.82e-1	1.62e-2
2	2.15e-5	8.55e-3	2.15e-5	8.07e-3

Listing 1. Revised DELTAED output for Case 1.

```
                        <<<  DELTAED  >>>

            <<< Delta - Eddington Radiative Transfer Model >>>

                    <<< Cycle Number    1 >>>

(1) Echo of input records:

SUNA          60.0      45.0
ATM1          12.0      0.55     14.00
ATM2           1.0    20.000     54.00     87.00
ATM2           2.0     6.000    463.00    600.00
ATM2           3.0     5.000    531.00    740.00
ATM2           4.0     3.000    540.00    810.00
ATM2           5.0     2.500    550.00    830.00
ATM2           6.0     1.500    694.00    900.00
ATM2           7.0     0.700    827.00   1000.00
ATM2           8.0     0.400    837.00   1100.00
ATM2           9.0     0.200    847.00   1200.00
ATM2          10.0     0.150    849.00   1200.00
ATM2          11.0    00.100    850.00   1200.00
ATM2          12.0    00.000   1028.00   1300.00
AERO           1.0     1.000    0.8042    1.0e-5
AERO           2.0     1.000    0.8042    1.0e-5
AERO           3.0     1.000    0.8042       0.0
AERO           4.0     1.000    0.8042       0.0
AERO           5.0     1.000    0.8042       0.0
AERO           6.0     1.000    0.8042       0.0
AERO           7.0     1.000    0.8042       0.0
AERO           8.0     1.000    0.8042       0.0
AERO           9.0     1.000    0.8042       0.0
AERO          10.0     1.000    0.8042       0.0
AERO          11.0     1.000    0.8042       0.0
PHF1           1.0       0.0
PHF1           2.0       0.0
PHF1           3.0       0.0
PHF1           4.0       0.0
PHF1           5.0       0.0
PHF1           6.0       0.0
PHF1           7.0       0.0
PHF1           8.0       0.0
PHF1           9.0       0.0
PHF1          10.0       0.0
PHF1          11.0       0.0
OBS1           1.0
OBS2           1.0       0.0       0.0    0.1010
TGT1           5.0
TGT2           1.0     0.000    3.0000    0.1010    90.000     0.000    0.1500
TGT2           2.0    2.1213    2.1213    0.1010    90.000    45.000    0.1500
TGT2           3.0    3.0000    0.0000    0.1010    90.000    90.000    0.1500
TGT2           4.0    2.1213   -2.1213    0.1010    90.000   135.000    0.1500
TGT2           5.0    0.0000   -3.0000    0.1010    90.000   180.000    0.1500
SURF           1.0 0.5081e-1
SGRA           0.0
DONE

(2) Atmospheric Model Parameters:

Layer   Base Height  Rayleigh Ext  Aerosol Ext  Total Ext   Total OPD
Number     <z>         <betar>       <betaa>     <beta>       <tau>
          (km )       (km**-1)      (km**-1)    (km**-1)
------  -----------  ------------  -----------  ---------   ---------

  1     6.0000E+00   3.2863E-03   1.0000E-05   3.2963E-03  4.6148E-02
  2     5.0000E+00   6.4099E-03   1.0000E-05   6.4199E-03  5.2568E-02
  3     3.0000E+00   7.4144E-03   2.4564E-02   3.1978E-02  1.1652E-01
```

4	2.5000E+00	7.8450E-03	3.6570E-02	4.4415E-02	1.3873E-01
5	1.5000E+00	8.2755E-03	8.1056E-02	8.9331E-02	2.2806E-01
6	7.0000E-01	9.0887E-03	1.5322E-01	1.6231E-01	3.5791E-01
7	4.0000E-01	1.0045E-02	1.9454E-01	2.0459E-01	4.1928E-01
8	2.0000E-01	1.1002E-02	2.2811E-01	2.3911E-01	4.6711E-01
9	1.5000E-01	1.1480E-02	2.3737E-01	2.4885E-01	4.7955E-01
10	1.0000E-01	1.1480E-02	2.4701E-01	2.5849E-01	4.9247E-01
11	0.0000E+00	1.1959E-02	2.6747E-01	2.7943E-01	5.2042E-01

(3) Surface Parameters:

Solar Zenith <thet0> (degrees)	Solar Azimuth <phi0> (degrees)	Surface Vis <vis> (km)	Total Atm OPD <taustar>	Surface Albedo <albedo>
6.0000E+01	4.5000E+01	1.4000E+01	5.2042E-01	5.0810E-02

Non-Lambertian bog surface selected

(4) Line of Sight Parameters:

LOS Number	LOS Zenith <thetob> (degrees)	LOS Azimuth <phiob> (degrees)	Path Rad <pthrd>	Surface Rad <surf0>	Total Rad <pthrd+surf>
1	90.000	0.000	1.751394E-01	1.957222E-02	1.841522E-01
2	90.000	45.000	4.468311E-01	1.957222E-02	4.558440E-01
3	90.000	90.000	1.751394E-01	1.957222E-02	1.841522E-01
4	90.000	135.000	8.235581E-02	1.957222E-02	9.136872E-02
5	90.000	180.000	6.523829E-02	5.389439E-02	9.005619E-02

Target Number	Target Normal Zenith Angle (degrees)	Target Normal Azimuth (degrees)	Target Albedo
1	90.000	0.000	0.1500
2	90.000	45.000	0.1500
3	90.000	90.000	0.1500
4	90.000	135.000	0.1500
5	90.000	180.000	0.1500

Listing 2. Revised DELTAED output for Case 2.

```
                         <<<  DELTAED  >>>

            <<< Delta - Eddington Radiative Transfer Model >>>

                       <<< Cycle Number    1 >>>


(1) Echo of input records:

SUNA           60.0    -45.0
ATM1           12.0     0.55     14.00
ATM2            1.0   20.000     54.00     87.00
ATM2            2.0    6.000    463.00    600.00
ATM2            3.0    5.000    531.00    740.00
ATM2            4.0    3.000    540.00    810.00
ATM2            5.0    2.500    550.00    830.00
ATM2            6.0    1.500    694.00    900.00
ATM2            7.0    0.700    827.00   1000.00
ATM2            8.0    0.400    837.00   1100.00
ATM2            9.0    0.200    847.00   1200.00
ATM2           10.0    0.150    849.00   1200.00
ATM2           11.0   00.100    850.00   1200.00
ATM2           12.0   00.000   1028.00   1300.00
AERO            1.0    1.000    0.8042    1.0e-5
AERO            2.0    1.000    0.8042    1.0e-5
AERO            3.0    1.000    0.8042       0.0
AERO            4.0    1.000    0.8042       0.0
AERO            5.0    1.000    0.8042       0.0
AERO            6.0    1.000    0.8042       0.0
AERO            7.0    1.000    0.8042       0.0
AERO            8.0    1.000    0.8042       0.0
AERO            9.0    1.000    0.8042       0.0
AERO           10.0    1.000    0.8042       0.0
AERO           11.0    1.000    0.8042       0.0
PHF1            1.0      0.0
PHF1            2.0      0.0
PHF1            3.0      0.0
PHF1            4.0      0.0
PHF1            5.0      0.0
PHF1            6.0      0.0
PHF1            7.0      0.0
PHF1            8.0      0.0
PHF1            9.0      0.0
PHF1           10.0      0.0
PHF1           11.0      0.0
OBS1            1.0
OBS2            1.0      0.0       0.0    0.1010
TGT1            5.0
TGT2            1.0    0.000    3.0000    0.1010    90.000     0.000    0.1500
TGT2            2.0   2.1213    2.1213    0.1010    90.000    45.000    0.1500
TGT2            3.0   3.0000    0.0000    0.1010    90.000    90.000    0.1500
TGT2            4.0   2.1213   -2.1213    0.1010    90.000   135.000    0.1500
TGT2            5.0   0.0000   -3.0000    0.1010    90.000   180.000    0.1500
SURF            1.0 0.5081e-1
SGRA            0.0
DONE

(2) Atmospheric Model Parameters:

Layer   Base Height  Rayleigh Ext  Aerosol Ext   Total Ext    Total OPD
Number     <z>         <betar>       <betaa>      <beta>        <tau>
          (km )       (km**-1)      (km**-1)     (km**-1)
------  -----------  ------------  -----------  -----------  ----------

  1     6.0000E+00   3.2863E-03    1.0000E-05   3.2963E-03   4.6148E-02
```

2	5.0000E+00	6.4099E-03	1.0000E-05	6.4199E-03	5.2568E-02
3	3.0000E+00	7.4144E-03	2.4564E-02	3.1978E-02	1.1652E-01
4	2.5000E+00	7.8450E-03	3.6570E-02	4.4415E-02	1.3873E-01
5	1.5000E+00	8.2755E-03	8.1056E-02	8.9331E-02	2.2806E-01
6	7.0000E-01	9.0887E-03	1.5322E-01	1.6231E-01	3.5791E-01
7	4.0000E-01	1.0045E-02	1.9454E-01	2.0459E-01	4.1928E-01
8	2.0000E-01	1.1002E-02	2.2811E-01	2.3911E-01	4.6711E-01
9	1.5000E-01	1.1480E-02	2.3737E-01	2.4885E-01	4.7955E-01
10	1.0000E-01	1.1480E-02	2.4701E-01	2.5849E-01	4.9247E-01
11	0.0000E+00	1.1959E-02	2.6747E-01	2.7943E-01	5.2042E-01

(3) Surface Parameters:

Solar Zenith <thet0> (degrees)	Solar Azimuth <phi0> (degrees)	Surface Vis <vis> (km)	Total Atm OPD <taustar>	Surface Albedo <albedo>
6.0000E+01	-4.5000E+01	1.4000E+01	5.2042E-01	5.0810E-02

Non-Lambertian bog surface selected

(4) Line of Sight Parameters:

LOS Number	LOS Zenith <thetob> (degrees)	LOS Azimuth <phiob> (degrees)	Path Rad <pthrd>	Surface Rad <surf0>	Total Rad <pthrd+surf>
1	90.000	0.000	1.751394E-01	1.957222E-02	1.841522E-01
2	90.000	45.000	8.235581E-02	1.957222E-02	9.136872E-02
3	90.000	90.000	6.523829E-02	5.389439E-02	9.005619E-02
4	90.000	135.000	6.106124E-02	6.811110E-02	9.242605E-02
5	90.000	180.000	6.523829E-02	5.389439E-02	9.005620E-02

Target Number	Target Normal Zenith Angle (degrees)	Target Normal Azimuth (degrees)	Target Albedo
1	90.000	0.000	0.1500
2	90.000	45.000	0.1500
3	90.000	90.000	0.1500
4	90.000	135.000	0.1500
5	90.000	180.000	0.1500

Listing 3. Revised DELTAED output for Case 3.

```
                         <<<  DELTAED  >>>

           <<< Delta - Eddington Radiative Transfer Model >>>

                    <<< Cycle Number   1 >>>


 (1) Echo of input records:


SUNA        60.0    -45.0
ATM1        12.0     0.55     14.00
ATM2         1.0   20.000     54.00     87.00
ATM2         2.0    6.000    463.00    600.00
ATM2         3.0    5.000    531.00    740.00
ATM2         4.0    3.000    540.00    810.00
ATM2         5.0    2.500    550.00    830.00
ATM2         6.0    1.500    694.00    900.00
ATM2         7.0    0.700    827.00   1000.00
ATM2         8.0    0.400    837.00   1100.00
ATM2         9.0    0.200    847.00   1200.00
ATM2        10.0    0.150    849.00   1200.00
ATM2        11.0   00.100    850.00   1200.00
ATM2        12.0   00.000   1028.00   1300.00
AERO         1.0    1.000    0.8042    1.0e-5
AERO         2.0    1.000    0.8042    1.0e-5
AERO         3.0    1.000    0.8042       0.0
AERO         4.0    1.000    0.8042       0.0
AERO         5.0    1.000    0.8042       0.0
AERO         6.0    1.000    0.8042       0.0
AERO         7.0    1.000    0.8042       0.0
AERO         8.0    1.000    0.8566     16.63
AERO         9.0    1.000    0.8042       0.0
AERO        10.0    1.000    0.8042       0.0
AERO        11.0    1.000    0.8042       0.0
PHF1         1.0      0.0
PHF1         2.0      0.0
PHF1         3.0      0.0
PHF1         4.0      0.0
PHF1         5.0      0.0
PHF1         6.0      0.0
PHF1         7.0      0.0
PHF1         8.0      0.0
PHF1         9.0      0.0
PHF1        10.0      0.0
PHF1        11.0      0.0
OBS1         1.0
OBS2         1.0      0.0       0.0    0.1010
TGT1         5.0
TGT2         1.0    0.000    3.0000    0.1010    90.000     0.000    0.1500
TGT2         2.0   2.1213    2.1213    0.1010    90.000    45.000    0.1500
TGT2         3.0   3.0000    0.0000    0.1010    90.000    90.000    0.1500
TGT2         4.0   2.1213   -2.1213    0.1010    90.000   135.000    0.1500
TGT2         5.0   0.0000   -3.0000    0.1010    90.000   180.000    0.1500
SURF         1.0 0.5306e-1
SGRA         0.0
DONE

 (2) Atmospheric Model Parameters:

Layer   Base Height  Rayleigh Ext  Aerosol Ext  Total Ext   Total OPD
Number     <z>         <betar>       <betaa>      <beta>      <tau>
          (km )       (km**-1)      (km**-1)     (km**-1)
------  -----------  ------------  -----------  ----------  ----------

  1     6.0000E+00   3.2863E-03    1.0000E-05   3.2963E-03  4.6148E-02
```

2	5.0000E+00	6.4099E-03	1.0000E-05	6.4199E-03	5.2568E-02
3	3.0000E+00	7.4144E-03	2.4564E-02	3.1978E-02	1.1652E-01
4	2.5000E+00	7.8450E-03	3.6570E-02	4.4415E-02	1.3873E-01
5	1.5000E+00	8.2755E-03	8.1056E-02	8.9331E-02	2.2806E-01
6	7.0000E-01	9.0887E-03	1.5322E-01	1.6231E-01	3.5791E-01
7	4.0000E-01	1.0045E-02	1.9454E-01	2.0459E-01	4.1928E-01
8	2.0000E-01	1.1002E-02	1.6630E+01	1.6641E+01	3.7475E+00
9	1.5000E-01	1.1480E-02	2.3737E-01	2.4885E-01	3.7599E+00
10	1.0000E-01	1.1480E-02	2.4701E-01	2.5849E-01	3.7729E+00
11	0.0000E+00	1.1959E-02	2.6747E-01	2.7943E-01	3.8008E+00

(3) Surface Parameters:

Solar Zenith <thet0> (degrees)	Solar Azimuth <phi0> (degrees)	Surface Vis <vis> (km)	Total Atm OPD <taustar>	Surface Albedo <albedo>
6.0000E+01	-4.5000E+01	1.4000E+01	3.8008E+00	5.3060E-02

Non-Lambertian bog surface selected

(4) Line of Sight Parameters:

LOS Number	LOS Zenith <thetob> (degrees)	LOS Azimuth <phiob> (degrees)	Path Rad <pthrd>	Surface Rad <surf0>	Total Rad <pthrd+surf>
1	90.000	0.000	9.797806E-02	2.424886E-02	1.091444E-01
2	90.000	45.000	8.053598E-02	2.424886E-02	9.170245E-02
3	90.000	90.000	7.726450E-02	2.429742E-02	8.845325E-02
4	90.000	135.000	7.627305E-02	2.431753E-02	8.747115E-02
5	90.000	180.000	7.726450E-02	2.429742E-02	8.845325E-02

Target Number	Target Normal Zenith Angle (degrees)	Target Normal Azimuth (degrees)	Target Albedo
1	90.000	0.000	0.1500
2	90.000	45.000	0.1500
3	90.000	90.000	0.1500
4	90.000	135.000	0.1500
5	90.000	180.000	0.1500

Listing 4. Revised DELTAED output for Case 4.

```
                    <<<  DELTAED  >>>

        <<< Delta - Eddington Radiative Transfer Model >>>

                <<< Cycle Number    1 >>>


(1) Echo of input records:


SUNA           60.0    -45.0
ATM1           12.0     0.55    14.00
ATM2            1.0   20.000    54.00     87.00
ATM2            2.0    6.000   463.00    600.00
ATM2            3.0    5.000   531.00    740.00
ATM2            4.0    3.000   540.00    810.00
ATM2            5.0    2.500   550.00    830.00
ATM2            6.0    1.500   694.00    900.00
ATM2            7.0    0.700   827.00   1000.00
ATM2            8.0    0.400   837.00   1100.00
ATM2            9.0    0.200   847.00   1200.00
ATM2           10.0    0.150   849.00   1200.00
ATM2           11.0   00.100   850.00   1200.00
ATM2           12.0   00.000  1028.00   1300.00
AERO            1.0    1.000   0.8042    1.0e-5
AERO            2.0    1.000   0.8042    1.0e-5
AERO            3.0    1.000   0.8042       0.0
AERO            4.0    1.000   0.8042       0.0
AERO            5.0    1.000   0.8042       0.0
AERO            6.0    1.000   0.8042       0.0
AERO            7.0    1.000   0.8042       0.0
AERO            8.0    1.000   0.8566     16.63
AERO            9.0    1.000   0.8042       0.0
AERO           10.0    1.000   0.8042       0.0
AERO           11.0    1.000   0.8042       0.0
PHF1            1.0      0.0
PHF1            2.0      0.0
PHF1            3.0      0.0
PHF1            4.0      0.0
PHF1            5.0      0.0
PHF1            6.0      0.0
PHF1            7.0      0.0
PHF1            8.0      0.0
PHF1            9.0      0.0
PHF1           10.0      0.0
PHF1           11.0      0.0
OBS1            1.0
OBS2            1.0      0.0      0.0    0.1010
TGT1            2.0
TGT2            1.0    0.000  100.000    0.1010    90.000    0.000   0.1000
TGT2            2.0    0.000   0.0010    0.1000    00.000   00.000   0.1500
SURF            1.0 0.5306e-1
SGRA            0.0
DONE

(2) Atmospheric Model Parameters:

Layer   Base Height   Rayleigh Ext   Aerosol Ext   Total Ext    Total OPD
Number     <z>          <betar>        <betaa>       <beta>       <tau>
          (km )        (km**-1)       (km**-1)     (km**-1)
------  -----------   ------------   -----------   ----------   ----------

  1     6.0000E+00    3.2863E-03     1.0000E-05    3.2963E-03   4.6148E-02
```

2	5.0000E+00	6.4099E-03	1.0000E-05	6.4199E-03	5.2568E-02
3	3.0000E+00	7.4144E-03	2.4564E-02	3.1978E-02	1.1652E-01
4	2.5000E+00	7.8450E-03	3.6570E-02	4.4415E-02	1.3873E-01
5	1.5000E+00	8.2755E-03	8.1056E-02	8.9331E-02	2.2806E-01
6	7.0000E-01	9.0887E-03	1.5322E-01	1.6231E-01	3.5791E-01
7	4.0000E-01	1.0045E-02	1.9454E-01	2.0459E-01	4.1928E-01
8	2.0000E-01	1.1002E-02	1.6630E+01	1.6641E+01	3.7475E+00
9	1.5000E-01	1.1480E-02	2.3737E-01	2.4885E-01	3.7599E+00
10	1.0000E-01	1.1480E-02	2.4701E-01	2.5849E-01	3.7729E+00
11	0.0000E+00	1.1959E-02	2.6747E-01	2.7943E-01	3.8008E+00

(3) Surface Parameters:

Solar Zenith <thet0> (degrees)	Solar Azimuth <phi0> (degrees)	Surface Vis <vis> (km)	Total Atm OPD <taustar>	Surface Albedo <albedo>
6.0000E+01	-4.5000E+01	1.4000E+01	3.8008E+00	5.3060E-02

Non-Lambertian bog surface selected

(4) Line of Sight Parameters:

LOS Number	LOS Zenith <thetob> (degrees)	LOS Azimuth <phiob> (degrees)	Path Rad <pthrd>	Surface Rad <surf0>	Total Rad <pthrd+surf>
1	90.000	0.000	1.816061E-01	1.616590E-02	1.816061E-01
2	135.000	0.000	2.145990E-05	1.775576E-01	1.775496E-01

Target Number	Target Normal Zenith Angle (degrees)	Target Normal Azimuth (degrees)	Target Albedo
1	90.000	0.000	0.1000
2	0.000	0.000	0.1500

Listing 5. Revised DELTAED output for CASE 5.

<<< DELTAED >>>

<<< Delta - Eddington Radiative Transfer Model >>>

<<< Cycle Number 1 >>>

(1) Echo of input records:

SUNA	60.0	-45.0					
ATM1	12.0	0.55	14.00				
ATM2	1.0	20.000	54.00	87.00			
ATM2	2.0	6.000	463.00	600.00			
ATM2	3.0	5.000	531.00	740.00			
ATM2	4.0	3.000	540.00	810.00			
ATM2	5.0	2.500	550.00	830.00			
ATM2	6.0	1.500	694.00	900.00			
ATM2	7.0	0.700	827.00	1000.00			
ATM2	8.0	0.400	837.00	1100.00			
ATM2	9.0	0.200	847.00	1200.00			
ATM2	10.0	0.150	849.00	1200.00			
ATM2	11.0	00.100	850.00	1200.00			
ATM2	12.0	00.000	1028.00	1300.00			
AERO	1.0	1.000	0.8042	1.0e-5			
AERO	2.0	1.000	0.8042	1.0e-5			
AERO	3.0	1.000	0.8042	0.0			
AERO	4.0	1.000	0.8042	0.0			
AERO	5.0	1.000	0.8042	0.0			
AERO	6.0	1.000	0.8042	0.0			
AERO	7.0	1.000	0.8042	0.0			
AERO	8.0	1.000	0.8566	16.63			
AERO	9.0	1.000	0.8042	0.0			
AERO	10.0	1.000	0.8042	0.0			
AERO	11.0	1.000	0.8042	0.0			
PHF1	1.0	0.0					
PHF1	2.0	0.0					
PHF1	3.0	0.0					
PHF1	4.0	0.0					
PHF1	5.0	0.0					
PHF1	6.0	0.0					
PHF1	7.0	0.0					
PHF1	8.0	0.0					
PHF1	9.0	0.0					
PHF1	10.0	0.0					
PHF1	11.0	0.0					
OBS1	1.0						
OBS2	1.0	0.0	0.0	0.1010			
TGT1	2.0						
TGT2	1.0	0.000	100.000	0.1010	90.000	0.000	0.1000
TGT2	2.0	0.000	0.0010	0.1000	00.000	00.000	-0.1500
SURF	1.0	0.5306e-1					
SGRA	0..0						
DONE							

(2) Atmospheric Model Parameters:

Layer Number	Base Height <z> (km)	Rayleigh Ext <betar> (km**-1)	Aerosol Ext <betaa> (km**-1)	Total Ext <beta> (km**-1)	Total OPD <tau>
1	6.0000E+00	3.2863E-03	1.0000E-05	3.2963E-03	4.6148E-02

2	5.0000E+00	6.4099E-03	1.0000E-05	6.4199E-03	5.2568E-02
3	3.0000E+00	7.4144E-03	2.4564E-02	3.1978E-02	1.1652E-01
4	2.5000E+00	7.8450E-03	3.6570E-02	4.4415E-02	1.3873E-01
5	1.5000E+00	8.2755E-03	8.1056E-02	8.9331E-02	2.2806E-01
6	7.0000E-01	9.0887E-03	1.5322E-01	1.6231E-01	3.5791E-01
7	4.0000E-01	1.0045E-02	1.9454E-01	2.0459E-01	4.1928E-01
8	2.0000E-01	1.1002E-02	1.6830E+01	1.6641E+01	3.7475E+00
9	1.5000E-01	1.1480E-02	2.3737E-01	2.4885E-01	3.7599E+00
10	1.0000E-01	1.1480E-02	2.4701E-01	2.5849E-01	3.7729E+00
11	0.0000E+00	1.1959E-02	2.6747E-01	2.7943E-01	3.8008E+00

(3) Surface Parameters:

Solar Zenith <thet0> (degrees)	Solar Azimuth <phi0> (degrees)	Surface Vis <vis> (km)	Total Atm OPD <taustar>	Surface Albedo <albedo>
6.0000E+01	-4.5000E+01	1.4000E+01	3.8008E+00	5.3060E-02

Non-Lambertian bog surface selected

(4) Line of Sight Parameters:

LOS Number	LOS Zenith <thetob> (degrees)	LOS Azimuth <phiob> (degrees)	Path Rad <pthrd>	Surface Rad <surf0>	Total Rad <pthrd+surf>
1	90.000	0.000	1.816061E-01	1.616590E-02	1.816061E-01
2	135.000	0.000	2.145990E-05	8.069286E-03	8.089407E-03

Target Number	Target Normal Zenith Angle (degrees)	Target Normal Azimuth (degrees)	Target Albedo
1	90.000	0.000	0.1000
2	0.000	0.000	0.1500

4.3 New Cases

The four new cases that illustrate the operation of the new version of the DELTAED model are described by the following list. The intention of this set of example cases is to demonstrate practical application of the S/G ratio calculation mode and the output plot file in the new version.

Case 1. This example shows S/G ratio results for an eastward-looking LOS over the course of a day for a location at 32 degrees north latitude and 106 degrees west longitude on 21 September. The time zone selected (-7 h) is appropriate to MST. The input local times straddle the sunrise and sunset times. Those input data cycles whose local times were before sunrise or after sunset were automatically skipped by DELTAED. The study wavelength is 0.55 μm and the surface visibility is 14 km. The ground surface is Lambertian with an albedo of 0.2. The observer is located 2 m above the coordinate origin. The sky target is on the same level as the observer at a distance of 100 km. The ground surface target is 200 m to the east of the observer. The aerosol phase function is of the Henyey-Greenstein type. The results for this case (that were contained in the DATAED.PLT file) were imported by a spreadsheet program and displayed using the spreadsheet's plotting utilities. The result is shown in figure 4. The output text (contained in the DATAED.OUT file) from this and the other cases in this section is not shown, as it is quite voluminous.

In the plot of S/G ratio and contrast transmission versus time, the nearly inverse relationship between these two quantities is apparent. The large peak in the S/G ratio early in the day is caused mainly by the higher sky path radiance due to forward scattering. There is also a slight increase in the S/G ratio at sunset due to a small backward peak in the phase function.

Case 2. Case 2 is identical to Case 1 except the ground surface and target surface are non-Lambertian and are appropriate to a forested surface. The results of this case are shown in figure 5.

The forested surface causes a marked increase in the S/G ratio for most of the day. Only in the nearly forward-scattering conditions near sunrise does the forest surface S/G ratio approach that for the Lambertian surface.

Case 3. The third case is the same as Case 2 except a thick haze layer of Deirmendjian Haze-L aerosol is used. The layer is 1 km thick, is situated between 2 and 3 km above ground level, and has an extinction coefficient of 1.956 km^{-1} (equivalent to a 2-km visibility). Figure 6 depicts some of the results for this case.

The results for this case show effects similar to those seen in Case 3 in the previous section. Note the much smoother variation of the S/G ratio over time and the lower morning and higher afternoon S/G values.

Case 4. This case is the same as Case 3 except an azimuthal scan of the LOS is made at a particular time of day (9:30 MST). The azimuthal dependence of the S/G ratio and contrast transmission are shown in figure 7.

Further evidence of the reduced S/G azimuthal dependence is seen here. Note also that the azimuthal peak in the S/G ratio is not at the solar azimuth (which was about 125 degrees for this time of day). This interesting effect is probably due to the asymmetry of the biconical reflection factors for the forested non-Lambertian surface.

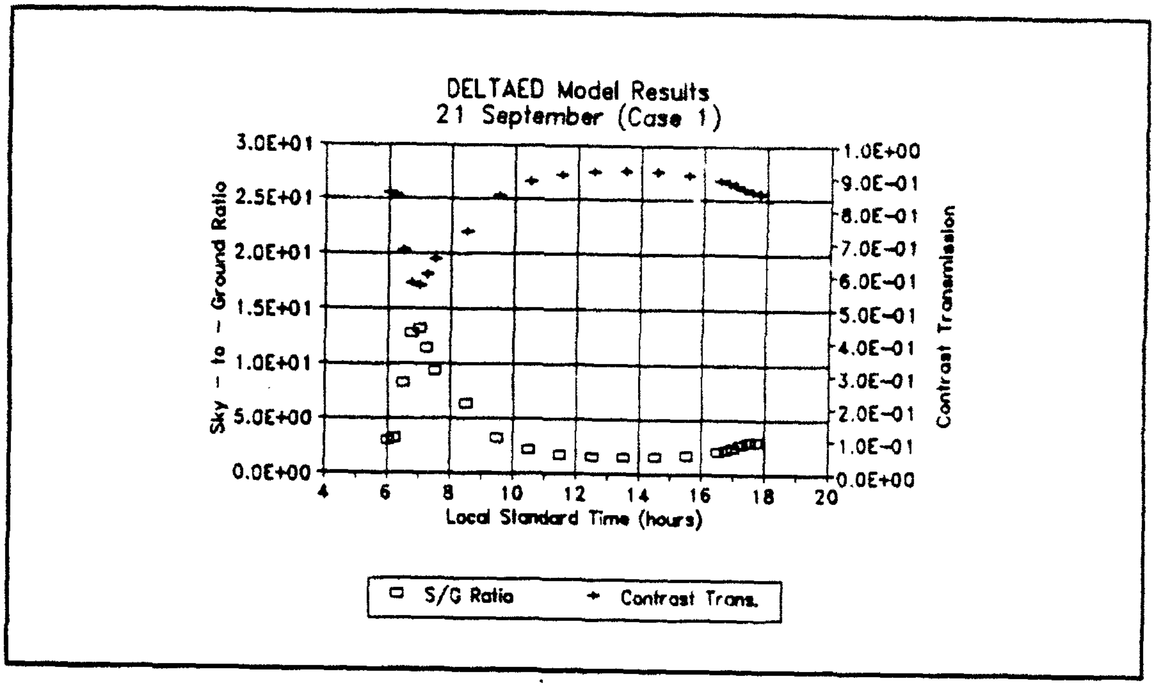

Figure 4. S/G ratio and contrast transmission for new Case 1.

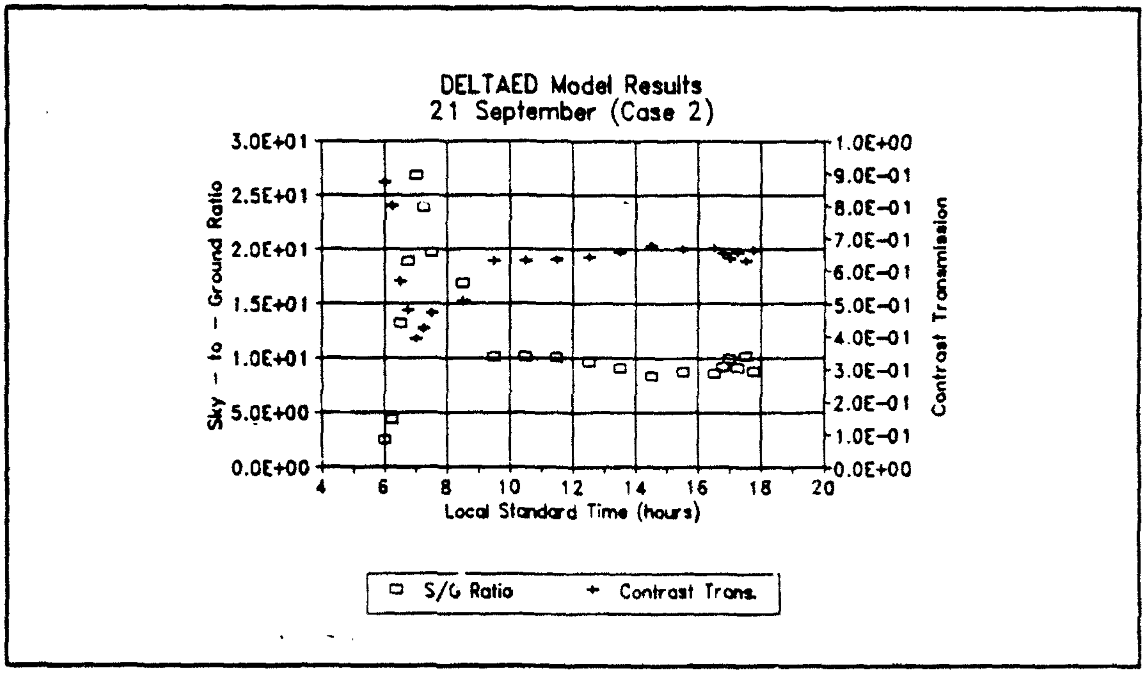

Figure 5. S/G ratio and contrast transmission for new Case 2.

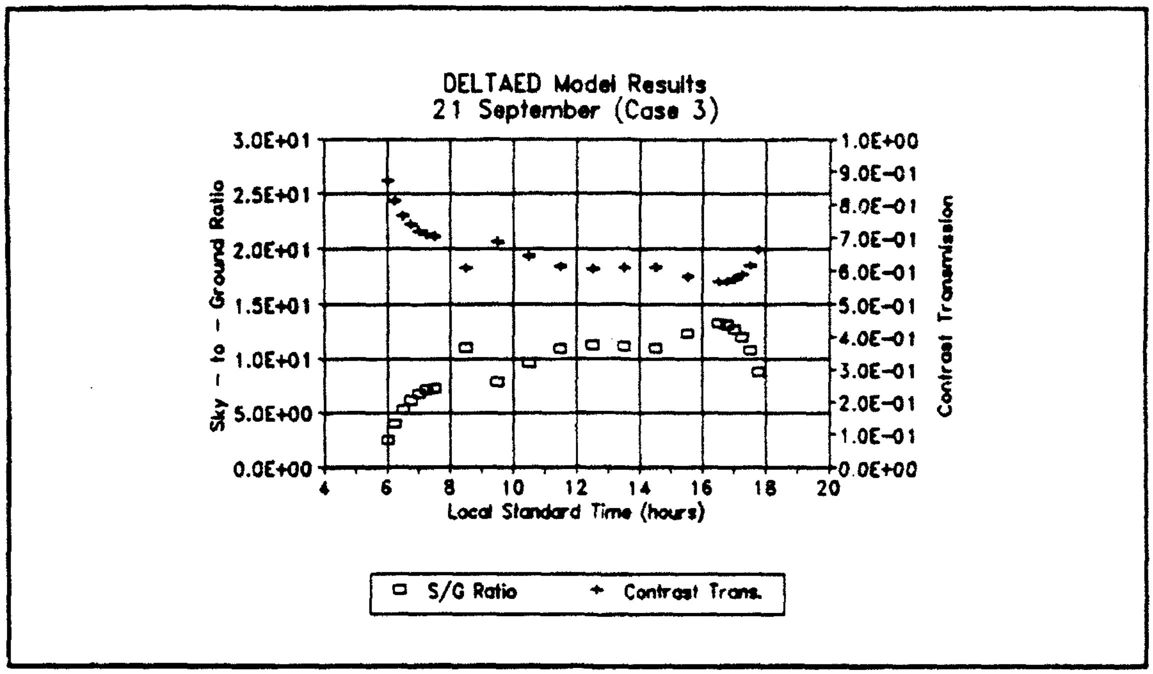

Figure 6. S/G ratio and contrast transmission for new Case 3.

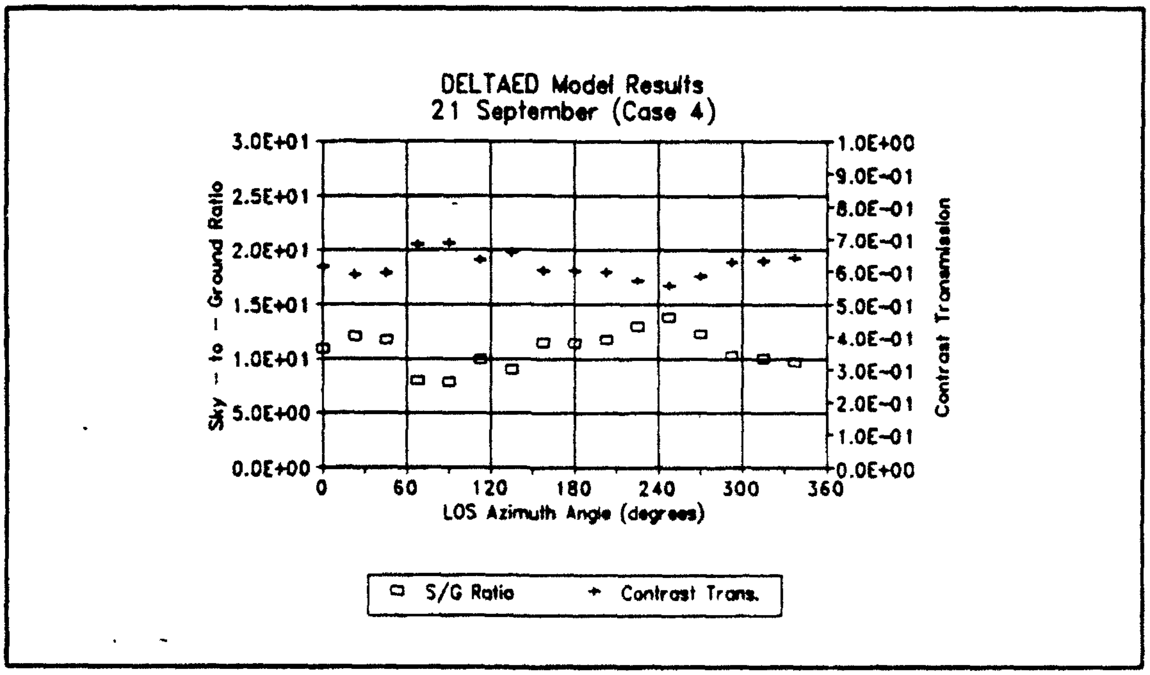

Figure 7. S/G ratio and contrast transmission for new Case 4.

Listing 6. Input deck for new Case 1.

```
SUNB     32.0   -106.0    05.00     21.0     09.0     -7.0
ATM1     11.0     0.55    14.00
ATM2      1.0   20.000   118.00   190.00
ATM2      2.0   10.000   257.00   410.00
ATM2      3.0    9.000   299.00   460.00
ATM2      4.0    8.000   347.00   520.00
ATM2      5.0    7.000   402.00   590.00
ATM2      6.0    6.000   463.00   660.00
ATM2      7.0    4.500   531.00   740.00
ATM2      8.0    3.000   608.00   830.00
ATM2      9.0    2.000   694.00   920.00
ATM2     10.0    0.700   827.00  1100.00
ATM2     11.0   00.000   897.00  1200.00
AERO      1.0    0.990   0.8042   8.0E-5
AERO      2.0    0.990   0.8042   9.0E-5
AERO      3.0    0.990   0.8042   1.0E-4
AERO      4.0    0.990   0.8042   1.0E-4
AERO      5.0    0.990   0.8042   1.0E-4
AERO      6.0    0.990   0.8042   5.0E-3
AERO      7.0    0.990   0.8042      0.0
AERO      8.0    0.990   0.8042      0.0
AERO      9.0    0.990   0.8042      0.0
AERO     10.0    0.990   0.8042      0.0
PHF1      1.0      0.0
PHF1      2.0      0.0
PHF1      3.0      0.0
PHF1      4.0      0.0
PHF1      5.0      0.0
PHF1      6.0      0.0
PHF1      7.0      0.0
PHF1      8.0      0.0
PHF1      9.0      0.0
PHF1     10.0      0.0
OBS1      1.0
OBS2      1.0      0.0      0.0    0.002
TGT1      2.0
TGT2      1.0  100.000  000.000    0.002    0.000   90.000    0.000
TGT2      2.0    0.200  000.000    0.000    0.000   00.000    0.200
SURF      0.0      0.2
SGRA      1.0
GO
SUNB     32.0   -106.0    05.15     21.0     09.0     -7.0
GO
SUNB     32.0   -106.0    05.30     21.0     09.0     -7.0
GO
SUNB     32.0   -106.0    05.45     21.0     09.0     -7.0
GO
SUNB     32.0   -106.0    06.00     21.0     09.0     -7.0
GO
SUNB     32.0   -106.0    06.15     21.0     09.0     -7.0
GO
SUNB     32.0   -106.0    06.30     21.0     09.0     -7.0
GO
SUNB     32.0   -106.0    06.45     21.0     09.0     -7.0
GO
SUNB     32.0   -106.0    07.00     21.0     09.0     -7.0
GO
SUNB     32.0   -106.0    07.15     21.0     09.0     -7.0
GO
SUNB     32.0   -106.0    07.30     21.0     09.0     -7.0
GO
SUNB     32.0   -106.0    08.30     21.0     09.0     -7.0
GO
SUNB     32.0   -106.0    09.30     21.0     09.0     -7.0
GO
SUNB     32.0   -106.0    10.30     21.0     09.0     -7.0
GO
SUNB     32.0   -106.0    11.30     21.0     09.0     -7.0
GO
SUNB     32.0   -106.0    12.30     21.0     09.0     -7.0
```

```
GO
SUNB          32.0    -106.0    13.30    21.0    09.0    -7.0
GO
SUNB          32.0    -106.0    14.30    21.0    09.0    -7.0
GO
SUNB          32.0    -106.0    15.30    21.0    09.0    -7.0
GO
SUNB          32.0    -106.0    16.30    21.0    09.0    -7.0
GO
SUNB          32.0    -106.0    16.45    21.0    09.0    -7.0
GO
SUNB          32.0    -106.0    17.00    21.0    09.0    -7.0
GO
SUNB          32.0    -106.0    17.15    21.0    09.0    -7.0
GO
SUNB          32.0    -106.0    17.30    21.0    09.0    -7.0
GO
SUNB          32.0    -106.0    17.45    21.0    09.0    -7.0
GO
SUNB          32.0    -106.0    18.00    21.0    09.0    -7.0
GO
SUNB          32.0    -106.0    18.15    21.0    09.0    -7.0
GO
SUNB          32.0    -106.0    18.30    21.0    09.0    -7.0
GO
SUNB          32.0    -106.0    18.45    21.0    09.0    -7.0
GO
SUNB          32.0    -106.0    19.00    21.0    09.0    -7.0
DONE
```

Listing 7. Input deck for new Case 2.

```
SUNB   32.0   -106.0   05.00   21.0   09.0   -7.0
ATM1   11.0    0.55    14.00
ATM2    1.0   20.000   118.00   190.00
ATM2    2.0   10.000   257.00   410.00
ATM2    3.0    9.000   299.00   460.00
ATM2    4.0    8.000   347.00   520.00
ATM2    5.0    7.000   402.00   590.00
ATM2    6.0    6.000   463.00   660.00
ATM2    7.0    4.500   531.00   740.00
ATM2    8.0    3.000   608.00   830.00
ATM2    9.0    2.000   694.00   920.00
ATM2   10.0    0.700   827.00  1100.00
ATM2   11.0   00.000   897.00  1200.00
AERO    1.0    0.990   0.8042   8.0E-5
AERO    2.0    0.990   0.8042   9.0E-5
AERO    3.0    0.990   0.8042   1.0E-4
AERO    4.0    0.990   0.8042   1.0E-4
AERO    5.0    0.990   0.8042   1.0E-4
AERO    6.0    0.990   0.8042   5.0E-3
AERO    7.0    0.990   0.8042   0.0
AERO    8.0    0.990   0.8042   0.0
AERO    9.0    0.990   0.8042   0.0
AERO   10.0    0.990   0.8042   0.0
PHF1    1.0    0.0
PHF1    2.0    0.0
PHF1    3.0    0.0
PHF1    4.0    0.0
PHF1    5.0    0.0
PHF1    6.0    0.0
PHF1    7.0    0.0
PHF1    8.0    0.0
PHF1    9.0    0.0
PHF1   10.0    0.0
OBS1    1.0
OBS2    1.0    0.0     0.0     0.002
TGT1    2.0
TGT2    1.0  100.000  000.000   0.002   0.000   90.000   0.000
TGT2    2.0    0.200  000.000   0.000   0.000   00.000  -0.200
SURF    2.0    0.2
SGRA    1.0
GO
SUNB   32.0   -106.0   05.15   21.0   09.0   -7.0
GO
SUNB   32.0   -106.0   05.30   21.0   09.0   -7.0
GO
SUNB   32.0   -106.0   05.45   21.0   09.0   -7.0
GO
SUNB   32.0   -106.0   06.00   21.0   09.0   -7.0
GO
SUNB   32.0   -106.0   06.15   21.0   09.0   -7.0
GO
SUNB   32.0   -106.0   06.30   21.0   09.0   -7.0
GO
SUNB   32.0   -106.0   06.45   21.0   09.0   -7.0
GO
SUNB   32.0   -106.0   07.00   21.0   09.0   -7.0
GO
SUNB   32.0   -106.0   07.15   21.0   09.0   -7.0
GO
SUNB   32.0   -106.0   07.30   21.0   09.0   -7.0
GO
SUNB   32.0   -106.0   08.30   21.0   09.0   -7.0
GO
SUNB   32.0   -106.0   09.30   21.0   09.0   -7.0
GO
SUNB   32.0   -106.0   10.30   21.0   09.0   -7.0
GO
SUNB   32.0   -106.0   11.30   21.0   09.0   -7.0
GO
```

```
SUNB      32.0   -106.0   12.30   21.0   09.0   -7.0
GO
SUNB      32.0   -106.0   13.30   21.0   09.0   -7.0
GO
SUNB      32.0   -106.0   14.30   21.0   09.0   -7.0
GO
SUNB      32.0   -106.0   15.30   21.0   09.0   -7.0
GO
SUNB      32.0   -106.0   16.30   21.0   09.0   -7.0
GO
SUNB      32.0   -106.0   16.45   21.0   09.0   -7.0
GO
SUNB      32.0   -106.0   17.00   21.0   09.0   -7.0
GO
SUNB      32.0   -106.0   17.15   21.0   09.0   -7.0
GO
SUNB      32.0   -106.0   17.30   21.0   09.0   -7.0
GO
SUNB      32.0   -106.0   17.45   21.0   09.0   -7.0
GO
SUNB      32.0   -106.0   18.00   21.0   09.0   -7.0
GO
SUNB      32.0   -106.0   18.15   21.0   09.0   -7.0
GO
SUNB      32.0   -106.0   18.30   21.0   09.0   -7.0
GO
SUNB      32.0   -106.0   18.45   21.0   09.0   -7.0
GO
SUNB      32.0   -106.0   19.00   21.0   09.0   -7.0
DONE
```

Listing 8. Input deck for new Case 3.

```
SUNB          32.0    -106.0     05.00      21.0      09.0     -7.0
ATM1          11.0      0.55     14.00
ATM2           1.0    20.000    118.00    190.00
ATM2           2.0    10.000    257.00    410.00
ATM2           3.0     9.000    299.00    460.00
ATM2           4.0     8.000    347.00    520.00
ATM2           5.0     7.000    402.00    590.00
ATM2           6.0     6.000    463.00    660.00
ATM2           7.0     4.500    531.00    740.00
ATM2           8.0     3.000    608.00    830.00
ATM2           9.0     2.000    694.00    920.00
ATM2          10.0     0.700    827.00   1100.00
ATM2          11.0    00.000    897.00   1200.00
AERO           1.0     0.990    0.8042    8.0E-5
AERO           2.0     0.990    0.8042    9.0E-5
AERO           3.0     0.990    0.8042    1.0E-4
AERO           4.0     0.990    0.8042    1.0E-4
AERO           5.0     0.990    0.8042    1.0E-4
AERO           6.0     0.990    0.8042    5.0E-3
AERO           7.0     0.990    0.8042       0.0
AERO           8.0 9.000E-01 8.055E-01    1.9560
AERO           9.0     0.990    0.8042       0.0
AERO          10.0     0.990    0.8042       0.0
PHF1           1.0       0.0
PHF1           2.0       0.0
PHF1           3.0       0.0
PHF1           4.0       0.0
PHF1           5.0       0.0
PHF1           6.0       0.0
PHF1           7.0       0.0
PHF1           8.0      65.0
PHF1           9.0       0.0
PHF1          10.0       0.0
PHF2           8.0       1.0    0.0000 2.408E+00
PHF2           8.0       2.0    0.5000 2.404E+00
PHF2           8.0       3.0    1.0000 2.394E+00
PHF2           8.0       4.0    2.0000 2.355E+00
PHF2           8.0       5.0    3.0000 2.292E+00
PHF2           8.0       6.0    4.0000 2.209E+00
PHF2           8.0       7.0    5.0000 2.110E+00
PHF2           8.0       8.0    6.0000 2.000E+00
PHF2           8.0       9.0    8.0000 1.764E+00
PHF2           8.0      10.0   10.0000 1.528E+00
PHF2           8.0      11.0   12.0000 1.308E+00
PHF2           8.0      12.0   14.0000 1.110E+00
PHF2           8.0      13.0   16.0000 9.385E-01
PHF2           8.0      14.0   18.0000 7.909E-01
PHF2           8.0      15.0   20.0000 6.657E-01
PHF2           8.0      16.0   24.0000 4.718E-01
PHF2           8.0      17.0   28.0000 3.359E-01
PHF2           8.0      18.0   32.0000 2.414E-01
PHF2           8.0      19.0   36.0000 1.753E-01
PHF2           8.0      20.0   40.0000 1.290E-01
PHF2           8.0      21.0   44.0000 9.619E-02
PHF2           8.0      22.0   48.0000 7.273E-02
PHF2           8.0      23.0   52.0000 5.577E-02
PHF2           8.0      24.0   56.0000 4.337E-02
PHF2           8.0      25.0   60.0000 3.421E-02
PHF2           8.0      26.0   64.0000 2.736E-02
PHF2           8.0      27.0   68.0000 2.219E-02
PHF2           8.0      28.0   72.0000 1.826E-02
PHF2           8.0      29.0   76.0000 1.524E-02
PHF2           8.0      30.0   80.0000 1.290E-02
PHF2           8.0      31.0   84.0000 1.109E-02
PHF2           8.0      32.0   88.0000 9.681E-03
PHF2           8.0      33.0   92.0000 8.584E-03
PHF2           8.0      34.0   96.0000 7.733E-03
PHF2           8.0      35.0  100.0000 7.082E-03
PHF2           8.0      36.0  104.0000 6.594E-03
```

PHF2	8.0	37.0	108.0000	6.245E-03			
PHF2	8.0	38.0	112.0000	6.018E-03			
PHF2	8.0	39.0	116.0000	5.901E-03			
PHF2	8.0	40.0	120.0000	5.889E-03			
PHF2	8.0	41.0	124.0000	5.978E-03			
PHF2	8.0	42.0	128.0000	6.167E-03			
PHF2	8.0	43.0	132.0000	6.457E-03			
PHF2	8.0	44.0	136.0000	6.843E-03			
PHF2	8.0	45.0	140.0000	7.318E-03			
PHF2	8.0	46.0	142.0000	7.584E-03			
PHF2	8.0	47.0	144.0000	7.865E-03			
PHF2	8.0	48.0	146.0000	8.159E-03			
PHF2	8.0	49.0	148.0000	8.463E-03			
PHF2	8.0	50.0	150.0000	8.773E-03			
PHF2	8.0	51.0	152.0000	9.085E-03			
PHF2	8.0	52.0	154.0000	9.395E-03			
PHF2	8.0	53.0	156.0000	9.694E-03			
PHF2	8.0	54.0	158.0000	9.969E-03			
PHF2	8.0	55.0	160.0000	1.020E-02			
PHF2	8.0	56.0	162.0000	1.034E-02			
PHF2	8.0	57.0	164.0000	1.033E-02			
PHF2	8.0	58.0	166.0000	1.011E-02			
PHF2	8.0	59.0	168.0000	9.672E-03			
PHF2	8.0	60.0	170.0000	9.080E-03			
PHF2	8.0	61.0	172.0000	8.569E-03			
PHF2	8.0	62.0	174.0000	8.477E-03			
PHF2	8.0	63.0	176.0000	8.950E-03			
PHF2	8.0	64.0	178.0000	9.664E-03			
PHF2	8.0	65.0	180.0000	1.001E-02			
OBS1	1.0						
OBS2	1.0	0.0	0.0	0.002			
TGT1	2.0						
TGT2	1.0	100.000	000.000	0.002	0.000	90.000	0.000
TGT2	2.0	0.200	000.000	0.000	0.000	00.000	-0.200
SURF	2.0	0.2					
SGRA	1.0						
GO							
SUNB	32.0	-106.0	05.15	21.0	09.0	-7.0	
GO							
SUNB	32.0	-106.0	05.30	21.0	09.0	-7.0	
GO							
SUNB	32.0	-106.0	05.45	21.0	09.0	-7.0	
GO							
SUNB	32.0	-106.0	06.00	21.0	09.0	-7.0	
GO							
SUNB	32.0	-106.0	06.15	21.0	09.0	-7.0	
GO							
SUNB	32.0	-106.0	06.30	21.0	09.0	-7.0	
GO							
SUNB	32.0	-106.0	06.45	21.0	09.0	-7.0	
GO							
SUNB	32.0	-106.0	07.00	21.0	09.0	-7.0	
GO							
SUNB	32.0	-106.0	07.15	21.0	09.0	-7.0	
GO							
SUNB	32.0	-106.0	07.30	21.0	09.0	-7.0	
GO							
SUNB	32.0	-106.0	08.30	21.0	09.0	-7.0	
GO							
SUNB	32.0	-106.0	09.30	21.0	09.0	-7.0	
GO							
SUNB	32.0	-106.0	10.30	21.0	09.0	-7.0	
GO							
SUNB	32.0	-106.0	11.30	21.0	09.0	-7.0	
GO							
SUNB	32.0	-106.0	12.30	21.0	09.0	-7.0	
GO							
SUNB	32.0	-106.0	13.30	21.0	09.0	-7.0	
GO							
SUNB	32.0	-106.0	14.30	21.0	09.0	-7.0	
GO							
SUNB	32.0	-106.0	15.30	21.0	09.0	-7.0	
GO							

```
GO
SUNB        32.0   -106.0   16.30   21.0   09.0   -7.0
GO
SUNB        32.0   -106.0   16.45   21.0   09.0   -7.0
GO
SUNB        32.0   -106.0   17.00   21.0   09.0   -7.0
GO
SUNB        32.0   -106.0   17.15   21.0   09.0   -7.0
GO
SUNB        32.0   -106.0   17.30   21.0   09.0   -7.0
GO
SUNB        32.0   -106.0   17.45   21.0   09.0   -7.0
GO
SUNB        32.0   -106.0   18.00   21.0   09.0   -7.0
GO
SUNB        32.0   -106.0   18.15   21.0   09.0   -7.0
GO
SUNB        32.0   -106.0   18.30   21.0   09.0   -7.0
GO
SUNB        32.0   -106.0   18.45   21.0   09.0   -7.0
GO
SUNB        32.0   -106.0   19.00   21.0   09.0   -7.0
DONE
```

Listing 9. Input deck for new Case 4.

```
SUNB            32.0   -106.0    09.30     21.0      09.0     -7.0
ATM1            11.0     0.55    14.00
ATM2             1.0   20.000   118.00   190.00
ATM2             2.0   10.000   257.00   410.00
ATM2             3.0    9.000   298.00   460.00
ATM2             4.0    8.000   347.00   520.00
ATM2             5.0    7.000   402.00   590.00
ATM2             6.0    6.000   463.00   660.00
ATM2             7.0    4.500   531.00   740.00
ATM2             8.0    3.000   608.00   830.00
ATM2             9.0    2.000   694.00   920.00
ATM2            10.0    0.700   827.00  1100.00
ATM2            11.0   00.000   897.00  1200.00
AERO             1.0    0.990   0.8042   8.0E-5
AERO             2.0    0.990   0.8042   9.0E-5
AERO             3.0    0.990   0.8042   1.0E-4
AERO             4.0    0.990   0.8042   1.0E-4
AERO             5.0    0.990   0.8042   1.0E-4
AERO             6.0    0.990   0.8042   5.0E-3
AERO             7.0    0.990   0.8042      0.0
AERO             8.0 9.000E-01 8.055E-01 1.9560
AERO             9.0    0.990   0.8042      0.0
AERO            10.0    0.990   0.8042      0.0
PHF1             1.0      0.0
PHF1             2.0      0.0
PHF1             3.0      0.0
PHF1             4.0      0.0
PHF1             5.0      0.0
PHF1             6.0      0.0
PHF1             7.0      0.0
PHF1             8.0     65.0
PHF1             9.0      0.0
PHF1            10.0      0.0
PHF2             8.0      1.0   0.0000 2.408E+00
PHF2             8.0      2.0   0.5000 2.404E+00
PHF2             8.0      3.0   1.0000 2.394E+00
PHF2             8.0      4.0   2.0000 2.355E+00
PHF2             8.0      5.0   3.0000 2.292E+00
PHF2             8.0      6.0   4.0000 2.209E+00
PHF2             8.0      7.0   5.0000 2.110E+00
PHF2             8.0      8.0   6.0000 2.000E+00
PHF2             8.0      9.0   8.0000 1.764E+00
PHF2             8.0     10.0  10.0000 1.528E+00
PHF2             8.0     11.0  12.0000 1.308E+00
PHF2             8.0     12.0  14.0000 1.110E+00
PHF2             8.0     13.0  16.0000 9.385E-01
PHF2             8.0     14.0  18.0000 7.909E-01
PHF2             8.0     15.0  20.0000 6.657E-01
PHF2             8.0     16.0  24.0000 4.718E-01
PHF2             8.0     17.0  28.0000 3.359E-01
PHF2             8.0     18.0  32.0000 2.414E-01
PHF2             8.0     19.0  36.0000 1.753E-01
PHF2             8.0     20.0  40.0000 1.290E-01
PHF2             8.0     21.0  44.0000 9.619E-02
PHF2             8.0     22.0  48.0000 7.273E-02
PHF2             8.0     23.0  52.0000 5.577E-02
PHF2             8.0     24.0  56.0000 4.337E-02
PHF2             8.0     25.0  60.0000 3.421E-02
PHF2             8.0     26.0  64.0000 2.736E-02
PHF2             8.0     27.0  68.0000 2.219E-02
PHF2             8.0     28.0  72.0000 1.826E-02
PHF2             8.0     29.0  76.0000 1.524E-02
PHF2             8.0     30.0  80.0000 1.290E-02
PHF2             8.0     31.0  84.0000 1.109E-02
PHF2             8.0     32.0  88.0000 9.681E-03
PHF2             8.0     33.0  92.0000 8.584E-03
PHF2             8.0     34.0  96.0000 7.733E-03
PHF2             8.0     35.0 100.0000 7.082E-03
PHF2             8.0     36.0 104.0000 6.594E-03
```

PHF2	8.0	37.0	108.0000	6.245E-03			
PHF2	8.0	38.0	112.0000	6.018E-03			
PHF2	8.0	39.0	116.0000	5.901E-03			
PHF2	8.0	40.0	120.0000	5.889E-03			
PHF2	8.0	41.0	124.0000	5.978E-03			
PHF2	8.0	42.0	128.0000	6.167E-03			
PHF2	8.0	43.0	132.0000	6.457E-03			
PHF2	8.0	44.0	136.0000	6.843E-03			
PHF2	8.0	45.0	140.0000	7.318E-03			
PHF2	8.0	46.0	142.0000	7.584E-03			
PHF2	8.0	47.0	144.0000	7.865E-03			
PHF2	8.0	48.0	146.0000	8.159E-03			
PHF2	8.0	49.0	148.0000	8.463E-03			
PHF2	8.0	50.0	150.0000	8.773E-03			
PHF2	8.0	51.0	152.0000	9.085E-03			
PHF2	8.0	52.0	154.0000	9.395E-03			
PHF2	8.0	53.0	156.0000	9.694E-03			
PHF2	8.0	54.0	158.0000	9.969E-03			
PHF2	8.0	55.0	160.0000	1.020E-02			
PHF2	8.0	56.0	162.0000	1.034E-02			
PHF2	8.0	57.0	164.0000	1.033E-02			
PHF2	8.0	58.0	166.0000	1.011E-02			
PHF2	8.0	59.0	168.0000	9.672E-03			
PHF2	8.0	60.0	170.0000	9.080E-03			
PHF2	8.0	61.0	172.0000	8.569E-03			
PHF2	8.0	62.0	174.0000	8.477E-03			
PHF2	8.0	63.0	176.0000	8.950E-03			
PHF2	8.0	64.0	178.0000	9.664E-03			
PHF2	8.0	65.0	180.0000	1.001E-02			
OBS1	1.0						
OBS2	1.0	0.0	0.0	0.002			
TGT1	2.0						
TGT2	1.0	00.000	100.000	0.002	0.000	90.000	0.000
TGT2	2.0	0.000	000.200	0.000	0.000	00.000	-0.200
SURF	2.0	0.2					
SGRA	1.0						
GO							
TGT1	2.0						
TGT2	1.0000	38.2683	92.3880	0.0020	0.0000	0.0000	-0.2000
TGT2	2.0000	0.0765	0.1848	0.0000	0.0000	0.0000	-0.2000
GO							
TGT1	2.0						
TGT2	1.0000	70.7107	70.7107	0.0020	0.0000	0.0000	-0.2000
TGT2	2.0000	0.1414	0.1414	0.0000	0.0000	0.0000	-0.2000
GO							
TGT1	2.0						
TGT2	1.0000	92.3880	38.2683	0.0020	0.0000	0.0000	-0.2000
TGT2	2.0000	0.1848	0.0765	0.0000	0.0000	0.0000	-0.2000
GO							
TGT1	2.0						
TGT2	1.0000	100.0000	0.0000	0.0020	0.0000	0.0000	-0.2000
TGT2	2.0000	0.2000	0.0000	0.0000	0.0000	0.0000	-0.2000
GO							
TGT1	2.0						
TGT2	1.0000	92.3880	-38.2683	0.0020	0.0000	0.0000	-0.2000
TGT2	2.0000	0.1848	-0.0765	0.0000	0.0000	0.0000	-0.2000
GO							
TGT1	2.0						
TGT2	1.0000	70.7107	-70.7107	0.0020	0.0000	0.0000	-0.2000
TGT2	2.0000	0.1414	-0.1414	0.0000	0.0000	0.0000	-0.2000
GO							
TGT1	2.0						
TGT2	1.0000	38.2683	-92.3880	0.0020	0.0000	0.0000	-0.2000
TGT2	2.0000	0.0765	-0.1848	0.0000	0.0000	0.0000	-0.2000
GO							
TGT1	2.0						
TGT2	1.0000	0.0000	-100.0000	0.0020	0.0000	0.0000	-0.2000
TGT2	2.0000	0.0000	-0.2000	0.0000	0.0000	0.0000	-0.2000
GO							
TGT1	2.0						
TGT2	1.0000	-38.2683	-92.3880	0.0020	0.0000	0.0000	-0.2000
TGT2	2.0000	-0.0765	-0.1848	0.0000	0.0000	0.0000	-0.2000

```
GO
TGT1           2.0
TGT2        1.0000   -70.7107   -70.7107    0.0020    0.0000    0.0000   -0.2000
TGT2        2.0000    -0.1414    -0.1414    0.0000    0.0000    0.0000   -0.2000
GO
TGT1           2.0
TGT2        1.0000   -92.3880   -38.2683    0.0020    0.0000    0.0000   -0.2000
TGT2        2.0000    -0.1848    -0.0765    0.0000    0.0000    0.0000   -0.2000
GO
TGT1           2.0
TGT2        1.0000  -100.0000     0.0000    0.0020    0.0000    0.0000   -0.2000
TGT2        2.0000    -0.2000     0.0000    0.0000    0.0000    0.0000   -0.2000
GO
TGT1           2.0
TGT2        1.0000   -92.3880    38.2683    0.0020    0.0000    0.0000   -0.2000
TGT2        2.0000    -0.1848     0.0765    0.0000    0.0000    0.0000   -0.2000
GO
TGT1           2.0
TGT2        1.0000   -70.7107    70.7107    0.0020    0.0000    0.0000   -0.2000
TGT2        2.0000    -0.1414     0.1414    0.0000    0.0000    0.0000   -0.2000
GO
TGT1           2.0
TGT2        1.0000   -38.2683    92.3880    0.0020    0.0000    0.0000   -0.2000
TGT2        2.0000    -0.0765     0.1848    0.0000    0.0000    0.0000   -0.2000
GO
TGT1           2.0
TGT2        1.0000     0.0000   100.0000    0.0020    0.0000    0.0000   -0.2000
TGT2        2.0000     0.0000     0.2000    0.0000    0.0000    0.0000   -0.2000
DONE
```